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Pathogenicity of *Fusarium solani* (Mart.) Sacc. isolates derived from different plants towards the yellow lupine (*Lupinus luteus* L.) and the French bean (*Phaseolus vulgaris* L.)

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Abstract. The research was conducted to define *Fusarium solani* specialisation in infecting the yellow lupine and French bean as well as to select nonpathogenic isolates of the fungus to be used in biological control of pathogenic forms of the genus *Fusarium*. The experiment was conducted in test tubes and pots under laboratory conditions, at 10°C and 20°C with 29 *F. solani* isolates derived from different plants and from the soil. The pathogenicity of the studied isolates differed considerably. The isolates which were not excised from the yellow lupine and French bean also showed high pathogenicity, which points to lack of *F. solani* specialisation in those plants. Four of the investigated isolates proved to be slightly pathogenic. None of the obtained isolates was nonpathogenic.

Key words: *Fusarium solani*, *Lupinus luteus*, pathogenicity, *Phaseolus vulgaris*, root rot.

Introduction

Fusarium solani (Mart.) Sacc. is well known for its high pathogenicity towards numerous crops, especially pea, the broad bean and French bean (CHRISTOU, SNYDER 1962, BOOTH 1971, FILIPOWICZ, WAGNER 1991, KRAFT 1991). BOOTH (1971) distinguishes 18 special forms, including those pathogenic also towards lupine and bean, namely *F. solani* f. sp. *lupini* and *F. solani* f. sp. *phaseoli*. Numerous literature reports show that the pathogen occurs also in the rhizosphere of plants not mentioned so far as its hosts (LEVIS, PAPAVIZAS 1975, WAGNER 1983).

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This may suggest that there is no specialisation of *F. solani*, as observed also in earlier preliminary investigations (PAŃKA, SADOWSKI 1997, PAŃKA et al. 1997).

The concept of dividing this species into special forms was applied earlier to differentiate between pathogenic and saprophytic strains, which differ only in their capacity to infect some plant species (SNYDER, HANSEN 1940). It was believed that special forms were specific to one host; hence the Latin origin of the plant name. Thus *F. solani* forms infecting lupine (*Lupinus* ssp.) were referred to as *F. solani* f.sp. *lupini* and the forms infecting French bean (*Phaseolus vulgaris* L.) as *F. solani* f.sp. *phaseoli*. However, it turned out that the majority of special forms had a wide range of hosts; only some were observed to have a narrow specialisation. All that made it justifiable to investigate in more detail the specialisation of *F. solani* species in infecting the yellow lupine and French bean, especially that earlier research was incomplete (OYARZUN et al. 1993, WAGNER 1995, 1996).

The carried out experiments allowed for some initial justification for differentiating between those special forms for the studied crops. Additionally, an attempt was made to select *F. solani* nonpathogenic isolates to be used in the biological control of pathogenic *Fusarium* forms. Such a possibility was earlier confirmed by positive results of research on controlling diseases caused by *Fusarium* spp. with nonpathogenic strains of *F. oxysporum* (ALABOUVETTE, COUTEAUDIER 1992, OYARZUN et al. 1994).

Material and methods

The investigation of pathogenicity of the respective isolates was conducted on the Juno yellow lupine cultivar and the Aura French bean cultivar. The selected seeds showed a high germination energy and no infection symptoms. They were properly developed and undamaged. Twenty-five *F. solani* isolates collected by the authors in NE Poland, two isolates from the Bank of Pathogens, Institute of Plant Protection (IOR), Poznań as well as two from the Department of Plant Protection of the Opole University. To select the isolates, results of earlier research on their pathogenicity towards the plants they were isolated from were considered. The most and the least pathogenic isolates were applied. A complete list of the selected isolates is shown in Table 1. The experiments were conducted in test tubes and pots, under conditions of climatic growth chambers, at two temperatures: 10 ± 1°C as well as 20 ± 1°C (hereinafter referred to as 10 and 20°C).

Test tube experiment

The surface of the seeds was disinfected with a 0.1% sublimate and rinsed three times with sterile water. Next they were transferred to test tubes (3 cm across) with filter paper cylinders and 20 mL Hoagland's medium. Under sterile conditions a 14-day *F. solani* cultures inoculum, consisting of a medium disk with mycelium

Table 1. Basic information on the studied isolates of *F. solani*

Isolate code	Source of isolates	Forecrop and soil class	Collection site
Fp 2	Field pea roots of cv. Bart	rye, IVb	Mochełek*
Fp 7	Field pea roots cv. Saturn	oats, IVb	Mochełek*
Fp 57	Field pea roots cv. Grapis	winter triticale, IVa	Brzyskorzystew*
Ep 27	Garden pea roots cv. Piast	sugar beet, IIIa	Tarkowo Górne*
Ep 43	Garden pea roots cv. Piast	triticale, II	Wudzynek*
Ep 46	Garden pea roots cv. Piast	winter wheat, II	Wudzynek*
Ep 56	Garden pea roots cv. Piast	winter wheat, IVa	Kołodziejewo*
YI 6	Yellow lupine roots cv. Juno	rye, V	Włóki*
YI 12	Yellow lupine roots cv. Parys	field pea, barley and spring vetch	Karolewo*
YI 24	Yellow lupine roots cv. Juno	rye, V	Wybcz*
NI 1	Narrow-leaved lupine roots cv. Emir	rye, IVb	Chełmce*
NI 2	Narrow-leaved lupine roots cv. Emir	rye, V	Jarużyn*
WI 1	White lupine roots	–	IOR Poznań
Fb 3	Broad bean roots	–	IOR Poznań
Fb 4	Broad bean roots cv. Nadwiślański	winter wheat, IVa	Sobiejuchy*
Sv 2	Spring vetch roots cv. Szelejewska	alfalfa, IIIb	Włóki*
Sv 4	Spring vetch roots cv. Szelejewska grown in mixture	winter barley, IIIb	Sienno*
Sv 8	Spring vetch roots cv. Szelejewska	winter barley, IVa	Karolewo*
Bn 2	French bean roots cv. Nida	French bean, IIIa	Jaksice*
Se 1	Bird's foot roots cv. Bydgoska	fallow (1 year), V	Jarużyn*
Se 2	Bird's foot roots cv. Bydgoska	rye, V	Łabiszyn*
By 12	Spring barley roots grown in mixture	potatoes, IIIa	Łowinek*
O 1	Oat roots	potatoes, V	Minikowo*
O 4	Oat roots grown in mixture	potatoes, IV	Lubostroń*
Bt 3	Roots of sugar beet seedlings	–	Opole University
Bt 5	Roots of sugar beet seedlings	–	Opole University
S 6	Soil from winter wheat plantation	winter rape, IV	Mochełek*
S 24	Soil from winter barley plantation	early potatoes, IV	Mochełek*
S 25	Soil from winter barley plantation	garden pea, VI	Mochełek*

*Author's collection

(5 mm across) was placed onto the seeds. In the control test, the seeds were supplied with clean medium disks. The experiments were set in three replications, 5 test tubes each. After 21 days, the degree of root infection was defined according to a 9–degree scale (0-8°), namely:

0° – no symptoms, healthy roots and shoots
1° – slight infection, up to 10 of the root
2° – root infection from 11 to 20%
3° – root infection from 21 to 30%
4° – root infection from 31 to 40%
5° – root infection from 41 to 50%
6° – root infection from 51 to 60%
7° – root infection from 61 to 70%
8° – dead roots, infection over 70%, musty plants.

Pot experiment

The pot soil was infected with a suspension of spores and mycelium pieces of *F. solani*. A culture of each isolate was transferred to four Petri dishes. After 14 days, the colonies grown were collected into separate dishes and then mixed for 5 minutes in a homogeniser filled with 200 mL of sterile water, and next they were mixed with sterilised garden soil. In the control test, the mixture was obtained from clean medium. The pots were filled with the soil and left for 7 days at room temperature to let the pathogen mycelium develop. Then 10 seeds of each plant were sown into the pots and put into growth chambers. The experiments were conducted in three replications. After four weeks, the plants were carefully taken out from the soil, their roots were washed under running water and the infection degree was defined according to the same scale.

The degree of infection was used to calculate the index of root infection (DI), separately for each treatment, applying the Townsend and Heuberger's formula. The results obtained were subjected to analysis of variance. To compare the mean values, Tukey's test was applied.

Results

Yellow lupine

Significant differences in the pathogenicity of the isolates towards the yellow lupine were noted both in test tube and in pot experiments (Table 2).

In the test tube experiment, at a lower temperature, the lowest index of infection (DI < 20.0%) was observed for Fb 3 (DI = 8.3%), Yl 24 (DI = 8.3%), Bt 3 (DI = 12.5%), O 4 (DI = 15.0%) and Wl 1 (DI = 16.7%). The highest infection (DI > 50.0%) was observed for Ep 43 from garden pea (DI = 61.7%), S 6 from the soil (DI = 51.7%) as well as Bn 2 from the French bean (DI = 51.7%). The in-

fection index of the most pathogenic isolate derived from lupine (Yl 12) amounted to 22.5%. At 20°C, Fb 3 (DI = 16.7%), Yl 24 (DI = 16.7%), Bt 3 (DI = 20.8%) as well as Wl 1 (DI = 21.7%) constituted a group of the least significantly pathogenic cultures. The isolates from the soil proved to be the most pathogenic (S 6, S 24); here the infection index amounted to 100%. A similar degree of infection (DI > 90.0%) was observed for the plants treated with the *F. solani* cultures isolated from field pea Fp 7 (DI = 99.2%), yellow lupine Yl 12 (DI = 97.5%), French bean Bn 2 (DI = 93.3%) as well as the broad bean Fb 4 (DI = 93.3%). No significant impact of temperature on the pathogenicity of the Fb 3, Bt 3, Yl 24, Wl 1, Yl 6, O 4, Fp 57, Ep 56, Sv 2 and Ep 43 cultures was observed.

In the pot experiment at 10°C three cultures, namely Fb 3 (DI = 7.9%), Yl 24 (DI = 7.9%) and Wl 1 (DI = 10.8%) were found to be the least pathogenic and, together with the control test, constituted a homogenous group. The plants combined with the isolates derived from garden pea Ep 43 (DI = 49.6%), bird's-foot Se 1 (DI = 46.3%), French bean Bn 2 (DI = 43.8%), soil S 6 (DI = 43.3%), narrow-leaved lupine Nl 1 (DI = 42.9%), barley By 12 (DI = 42.1%) as well as spring vetch Sv 8 (DI = 41.7%) were the most significantly infected. At the higher temperature, the lowest infection was caused by the cultures of Bt 3 (DI = 17.9%), Yl 24 (DI = 17.9%), Fb 3 (DI = 21.7%) and Wl 1 (DI = 25.0%). A high degree of infection (DI > 90%) was caused by S 6 (DI = 96.7%), Fp 7 (DI = 94.6%), S 24 (DI = 93.3%), Yl 12 (DI = 90.4%) and Se 1 (DI = 90.0%). Similarly, a significant impact of temperature on the degree of pathogenicity of the studied isolates was noted, except for Bt 3, Yl 24 and Fp 57 which remained unaffected.

French bean

Both in the test tube and pot experiment, significant differences in the pathogenicity of the *F. solani* isolates were noted. Also in the majority of cases a significant influence of temperature on the pathogenicity of the tested cultures was observed (Table 3).

Under laboratory conditions, at the temperature of 10°C, the lowest infection was caused by Wl 1 (DI = 6.7%), Yl 24 (DI = 6.7%), Fb 3 (DI = 9.2%) and O 4 (DI = 16.7%). The highest degree of pathogenicity was noted for the cultures derived from the soil: S 6 (DI = 62.5%), S 24 (DI = 50.8%), as well as from the spring vetch, Sv 4 (DI = 49.2%). A slightly lower infection index value (47.5%) was noted for Bn 2 derived from the French bean, Fb 4 from the broad bean and Ep 27 from garden pea. When exposed to a higher temperature, the lowest infection was caused by the isolates derived from the white lupine Wl 1 (DI = 11.7%) and from the yellow lupine Yl 24 (DI = 11.7%), whereas S 6 (DI = 100%) and S 24 (DI = 95.8%) derived from the soil turned out to be the most highly pathogenic, as their infection index exceeded 90%. Ep 27 (DI = 89.2%) from garden pea, Bn 2

Table 2. Index of the yellow lupine root infection with selected *F. solani* isolates in tube and pot experiments

No.	Isolate code	Test tube experiment		Pot experiment	
		10°C	20°C	10°C	20°C
1	2	3	4	5	6
1	Fp 2	30.0 bcdef* a	85.0 ghi b	26.8 ef a	83.3 klmno b
2	Fp 7	31.7 bcdef a	99.2 I b	25.4 def a	94.6 no b
3	Fp 57	25.0 abcdef a	42.5 bcde a	20.0 bcdef a	33.3 cde a
4	Ep 27	33.3 bcdef a	85.8 ghi b	28.3 efg a	80.8 klm b
5	Ep 43	61.7 g a	86.7 ghi a	49.6 j a	81.3 klmn b
6	Ep 46	33.3 bcdef a	76.7 fghi b	26.3 ef a	64.2 hi b
7	Ep 56	23.3 abcde a	45.8 cde a	18.8 bcdef a	43.3 efg b
8	Yl 6	20.8 abcde a	32.5 bcd a	17.5 bcde a	36.3 def b
9	Yl 12	22.5 abcde a	97.5 hi b	22.9 cdef a	90.4 lmno b
10	Yl 24	8.3 ab a	16.7 ab a	7.9 ab a	17.9 b a
11	Nl 1	40.8 defg a	95.0 ghi b	42.9 ij a	88.3 lmno b
12	Nl 2	33.3 bcdef a	68.3 efg b	27.1 ef a	70.0 ijk b
13	Wl 1	16.7 abcde a	21.7 abc a	10.8 abc a	25.0 bcd b
14	Fb 3	8.3 ab a	16.7 ab a	7.9 ab a	21.7 bc b
15	Fb 4	30.8 bcdef a	93.3 ghi b	29.2 efgh a	89.2 lmno b
16	Sv 2	27.5 abcdef a	55.0 def a	23.3 cdef a	47.5 fg b
17	Sv 4	34.2 bcdefg a	80.8 fghi b	31.3 fghi a	78.8 jkl b
18	Sv 8	44.2 efg a	80.8 fghi b	41.7 ghij a	79.6 jkl b
19	Bn 2	51.7 fg a	93.3 ghi b	43.8 ij a	89.2 lmno b

1	2	3	4	5	6
20	Se1	41.7 defg a	89.2 ghi b	46.3 j a	90.0 lmno b
21	Se2	30.8 bcdef a	79.2 fghi b	25.0 def a	70.0 ijk b
22	By 12	40.0 cdefg a	89.2 ghi b	42.1 hij a	82.1 klmn b
23	O 1	32.5 bcdef a	70.0 efgh b	26.7 ef a	67.1 ij b
24	O 4	15.0 abcd a	37.5 bcd a	16.7 bcde a	32.5 cde b
25	Bt 3	12.5 abc a	20.8 abc a	10.8 abc a	17.9 b a
26	Bt 5	20.8 abcde a	56.7 def b	21.3 bcdef a	51.3 gh b
27	S 6	51.7 fg a	100.0 i b	43.3 ij a	96.7 o b
28	S 24	41.7 defg a	100.0 i b	32.1fghi a	93.3 mno b
29	S 25	26.7 abcdef a	56.7 def b	23.8 cdef a	50.0 g b
30	Control	0.0 a a	0.0 a a	0.0 a a	0.0 a a

* Mean values followed by the same letter in columns and rows are not significantly different at $\alpha = 0.05$ according to Tukey's test

(DI = 87.5%) from the French bean and Bt 5 (DI = 87.5 %) from sugar beet were slightly less pathogenic. No significant impact of temperature on plant root infection was noted for almost half of the isolates, namely Wl 1, Yl 24, Fb 3, By 12, Bt 3, O 4, Ep 56, Fp 57, Se 1, O 1, S 25, Yl 12, Ep 46 and Se 2.

In the pot experiment, at both temperatures, three isolates, namely Wl 1 from the white lupine (10°C, DI = 4.6%; 20°C, DI = 13.3%), Yl 24 from the yellow lupine (10°C, DI = 4.6%; 20°C, DI = 16.7%) and Fb 3 from the broad bean (10°C, DI = 7.0%; 20°C, DI = 16.7%) were found to be the least pathogenic.

The most considerable infection (DI > 50.0%) at 10°C was caused by two isolates from the soil, S 6 (DI = 55.8%) and S 24 (DI = 53.3%) as well as the isolate from the broad bean, Fb 4 (DI = 50.4%). Similarly, they were amongst the most pathogenic (DI > 80.0%) at the higher temperature; their infection indexes reached respectively: 93.3% for S 6, 92.5% for S 24 and 88.3% for Fb 4. That homogenous group also included Bn 2 (DI = 90.0%), Ep 27 (DI = 89.6%), Sv 4 (DI = 82.9%) as well as Bt 5 (DI = 78.3%). For most of the pathogens tested, the temperature showed to influence their pathogenicity significantly. Only Wl 1, Yl 24, Fb 3, Bt 3, Ep 56, S 25, Fp 57, Yl 12, Se 1 and Ep 46 caused a similar infection at both temperatures.

Table 3. Index of French bean root infection with selected *F. solani* isolates in tube and pot experiments

No.	Isolates code	Test tube experiment		Pot experiment	
		10°C	20°C	10°C	20°C
1	2	3	4	5	6
1	Fp 2	30.0 bcdef* a	85.0 ghi b	26.8 ef a	83.3 klmno b
2	Fp 7	31.7 bcdef a	99.2 I b	25.4 def a	94.6 no b
3	Fp 57	25.0 abcdef a	42.5 bcde a	20.0 bcdef a	33.3 cde a
4	Ep 27	33.3 bcdef a	85.8 ghi b	28.3 efg a	80.8 klm b
5	Ep 43	61.7 g a	86.7 ghi a	49.6 j a	81.3 klmn b
6	Ep 46	33.3 bcdef a	76.7 fghi b	26.3 ef a	64.2 hi b
7	Ep 56	23.3 abcde a	45.8 cde a	18.8 bcdef a	43.3 efg b
8	Yl 6	20.8 abcde a	32.5 bcd a	17.5 bcde a	36.3 def b
9	Yl 12	22.5 abcde a	97.5 hi b	22.9 cdef a	90.4 lmno b
10	Yl 24	8.3 ab a	16.7 ab a	7.9 ab a	17.9 b a
11	Nl 1	40.8 defg a	95.0 ghi b	42.9 ij a	88.3 lmno b
12	Nl 2	33.3 bcdef a	68.3 efg b	27.1 ef a	70.0 ijk b
13	Wl 1	16.7 abcde a	21.7 abc a	10.8 abc a	25.0 bcd b
14	Fb 3	8.3 ab a	16.7 ab a	7.9 ab a	21.7 bc b
15	Fb 4	30.8 bcdef a	93.3 ghi b	29.2 efgh a	89.2 lmno b
16	Sv 2	27.5 abcdef a	55.0 def a	23.3 cdef a	47.5 fg b
17	Sv 4	34.2 bcdefg a	80.8 fghi b	31.3 fghi a	78.8 jkl b
18	Sv 8	44.2 efg a	80.8 fghi b	41.7 ghij a	79.6 jkl b
19	Bn 2	51.7 fg a	93.3 ghi b	43.8 ij a	89.2 lmno b

1	2	3	4	5	6
20	Se1	41.7 defg a	89.2 ghi b	46.3 j a	90.0 lmno b
21	Se2	30.8 bcdef a	79.2 fghi b	25.0 def a	70.0 ijk b
22	By 12	40.0 cdefg a	89.2 ghi b	42.1 hij a	82.1 klmn b
23	O 1	32.5 bcdef a	70.0 efgh b	26.7 ef a	67.1 ij b
24	O 4	15.0 abcd a	37.5 bcd a	16.7 bcde a	32.5 cde b
25	Bt 3	12.5 abc a	20.8 abc a	10.8 abc a	17.9 b a
26	Bt 5	20.8 abcde a	56.7 def b	21.3 bcdef a	51.3 gh b
27	S 6	51.7 fg a	100.0 i b	43.3 ij a	96.7 o b
28	S 24	41.7 defg a	100.0 i b	32.1fghi a	93.3 mno b
29	S 25	26.7 abcdef a	56.7 def b	23.8 cdef a	50.0 g b
30	Control	0.0 a a	0.0 a a	0.0 a a	0.0 a a

* Mean values followed by the same letter in columns and rows are not significantly different at $\alpha = 0.05$ according to Tukey's test.

Discussion

The obtained results showed considerable differences in the pathogenicity of the *F. solani* isolates towards the yellow lupine and French bean; for the first one, also the cultures derived from the soil and pea, bird's-foot and French bean turned out to be the most pathogenic, apart from the isolates derived from lupines. Similar results were also obtained for the French bean. The most pathogenic, apart from the isolates derived from the same crop, were those derived from pea, the spring vetch, broad bean, sugar beet as well as the soil, which suggest no specialisation of *F. solani* in infecting the yellow lupine and the French bean. The obtained results confirm those of the preliminary investigations (PAŃKA, SADOWSKI 1997, PAŃKA et al. 1997). Similar research on physiological preferences of various pathogens responsible for pea root rot were conducted by OYARZUN et al. (1993); it was observed that *F. solani* isolates differed in the degree of their pathogenicity towards pea, the French bean and broad bean. Similar results were obtained by WAGNER (1995, 1996) who investigated the pathogenicity of various isolates of the same pathogen towards the broad bean, pea, winter

wheat and chickpea. Also the isolates not derived from them remained highly pathogenic towards those plants. Additionally, differences in the *F. solani* pathogenicity were observed.

The pathogenicity of the isolates depended on the plant being infected to some extent. Some isolates caused a similar infection of the plants used in the experiment, whereas others differed considerably as regards the degree of pathogenicity. It was also impossible to define any relationship between the degree of pathogenicity of a given isolate and its origin. Some of the isolates showed greater preferences to infecting plants cultivated on soils similar to those they were isolated from. However, there were also some isolates where no such a relationship was noted. Thus, despite all the effort made to analyse the results obtained, it was not possible to define any constant relationships between the degree of pathogenicity, the isolate origin or the forecrop. As it is known from the literature, *F. solani* growth, development and pathogenicity can be influenced by many various factors. OYARZUN et al. (1993) report that the degree of the pathogenicity of the fungus depends on crop-rotation forecrops. Similarly, microorganisms present in the soils of the crops, especially saprophytic organisms with an antagonistic potential, e.g. *Trichoderma* spp., *Gliocladium* spp., *Bacillus* spp. as well as fluorescent *Pseudomonas* spp. (NEWEIGY et al. 1982) have a considerable impact here. Similarly, *F. solani* can be also modified by root secretions (CHRISTIAN, HADWIGER 1989, WELTRING et al. 1992), its enzymatic activity (ROGERS et al. 1994), chemical compounds introduced into the soil (BURGIEŁ 1989), the occurrence of bacteria of the genus *Rhizobium* on the seeds (CHAKRABORTY, CHAKRABORTY 1989), soil type (SADOWSKI, SOWA 1989), and many other factors.

The results obtained seem to confirm lack of specialisation of *F. solani* to infect on of the yellow lupine and the French bean as well as a marked influence of various factors on *F. solani*; thus it does not seem justifiable to define any special forms of this pathogen infecting the plants investigated.

As a result of the research conducted, no nonpathogenic *F. solani* cultures were isolated. However, four isolates, namely Yl 24, Wl 1, Fb 3 and Bt 3, were found to be slightly pathogenic towards the yellow lupine and the French bean. Their slight pathogenicity could have been due to the very favourable experimental conditions for the development of *F. solani*. Further research may show that under natural conditions the isolates would be nonpathogenic, hence showing a potential for controlling pathogenic *Fusarium* spp. Such a possibility was confirmed by the research conducted by OYARZUN et al. (1994), CHAKRABORTY, GUPTA (1995) as well as in relation to nonpathogenic isolates of *F. oxysporum* and *F. solani*. A further study is needed to investigate whether or not the isolates selected can be applied as controlling agents.

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