ACTA MYCOLOGICA
Vol. 35 (2): 275–290
2000

Effect of soil fungi communities on the growth of damping-off pathogens in relation to incubation temperature and medium pH

MAŁGORZATA KACPRZAK[1] and MAŁGORZATA MAŃKA[2]

[1] Institute of Environmental Engineering, Technical University of Częstochowa
Dąbrowskiego 69, PL-42-200 Częstochowa, Poland
[2] Department of Forest Pathology, August Cieszkowski Academy of Agriculture
Wojska Polskiego 71 c, PL-60-625 Poznań, Poland

K a c p r z a k M., M a ń k a M.: *Effect of soil fungi communities on the growth of damping-off pathogens in relation to incubation temperature and medium pH.* Acta Mycol. 35 (2): 275–290, 2000.

Four communities of saprotrophic fungi from a forest nursery soil were tested for their effect on the *in vitro* growth of damping-off pathogens: *Rhizoctonia solani, Fusarium avenaceum, F. culmorum, F. oxysporum* and *F. solani* in relation to incubation temperature (5, 10, 15, 20 or 25°C) and medium pH (4.3; 5.6 or 7.5).

The soil fungi communities weakly suppressed the growth of pathogens studied only at the lower temperatures (5 or 10°C). At the higher temperatures the communities tested supported the growth of all pathogens. The supporting effect was increasing with the increase of temperature, independently of pH. The effect was highly dependent on incubation temperature and not dependent on medium pH ($P < 0.05$, analysis of variance).

Duncan's multiple range tests indicate no significant differences (in the majority of combinations) in the effect of soil fungi communities on the *in vitro* growth of tested pathogens between temperatures 15, 20 and 25°C, independently of medium pH.

The growth of the pathogens studied was suppressed mainly by: *Gliocladium catenulatum, Trichoderma atroviride, T. koningii, T. viride, Truncatella truncata* and *Zygorrhynchus moelleri.*

Key words: pine, biotic effect, soil fungi, damping-off pathogens, temperature, pH.

INTRODUCTION

The microbial soil investigations and research on biotic relationships between microorganisms resulted in development of methods of plant protection against pathogens, including damping-off pathogens (S t r z e l c z y k 1988). Communities of fungi may be concerned representative for the complex of ecological factors occurring in the plant environment. In turn, a given fungal community, inhabiting the soil environment of the plant, effects the growth of soil pathogens (M a ń k a 1974, 1998). From G a r r e t t's (1965) point

of view biological protection of plants against diseases is possible through the introduction of antagonistic microorganisms into the soil or creating such conditions in the soil, which could suppress or even kill a pathogen. Furthermore, it was shown that environmental factors, such as water content, temperature and nutrient substances may influence the interactions between fungi (M a g a n and L a c e y 1984). This conclusion is relevant to the problem of proper plant rotation, soil pH, moisture or temperature occurring under natural conditions. Hence, environmental factors not only effect directly plant development but through their influence on the saprotrophic fungal communities they could help in restriction of the growth of pathogenic fungi (G i e r c z a k 1972; M a ń k a 1998; M a ń k a 1995).

The aim of this study was an *in vitro* investigation on the effect of saprotrophic fungi communities from the soil environment of Scots pine seedlings on the growth of damping-off pathogens in relation to incubation temperature and medium pH.

The work was supported by the Committee for Scientific Research, project number 5PO6H05816.

MATERIALS AND METHODS

The following forest nurseries were chosen for the study:

1. Forest nursery Garncarskibród (Oborniki Wielkopolskie Forest District) situated within the Wielkopolsko-Pomorski Region (Central-West Poland). The samples of soil and diseased seedlings were taken on June 3, 1996, from two beds with the following rotation:

bed IV (first type): 1993 – mountain ash (*Sorbus aucuparia* L.) and birch (*Betula pendula* Roth.), 1994 – fallow and birch, 1995 – fallow, 1996 – Scots pine (*Pinus sylvestris* L.)

bed VI (second type): 1993 – Norway spruce (*Picea abies* Karst.), 1994 – fallow, 1995 – Scots pine, 1996 – Scots pine

2. Forest nursery Kukawy (Kowal Forest District) situated within the Wielkopolsko-Pomorski Region. Diseased seedlings were sampled on June 10, 1996 (from bed III and VI) and on June 2, 1997. The samples of soil were taken on June 2, 1997, from two beds with the following rotation:

bed II (first type): 1994 – birch, 1995 – birch, 1996 – fallow, 1997 – Scots pine;

bed VII (second type): 1994 – Norway spruce, 1995 – fallow, 1996 – Scots pine, 1997 – Scots pine

Additionally, the seedlings of *Pinus nigra* Arn. with damping-off symptoms were taken on June 18, 1997 from the forest nursery Grodziec (Siewierz Forest District) situated within the Silesia Region. The seedlings were grown in *Sphagnum* peat in plastic tunnel.

Soil pH analyses of samples from the Oborniki Forest District were performed in the Department of Pedology and Fertilization, University of Agriculture, Poznań and in the Department of Pedology and Fertilization of Forest Research Institute in Sękocin – in the case of samples from the Kowal Forest District. The pH of peat substrate used in the Grodziec nursery was measured by the producer ("Hol Las" Pasłęk).

Pathogens were isolated from diseased seedlings according to Gierczak, Mańka and Przezbórski (1987). Identification of species was achieved – in the case of *Rhizoctonia solani* according to Bandoni (1979) and Mikołajska and Wachowska (1996), and in the case of *Fusarium* spp. according to Kwaśna, Chełkowski and Zajkowski (1991).

The following pathogens were chosen for the biotic series tests:
isolated in 1996:
Rhizoctonia solani Kühn from bed VI, Garncarskibród nursery (described as *R. solani* 96)
Fusarium solani (Mart.) Sacc. from bed IV, Garncarskibród nursery (described as *F. solani* 96)
F. culmorum (Smith) Sacc. from bed III, Kukawy nursery (described as *F. culmorum* 96)
F. oxysporum Schlecht. from bed VI, Kukawy nursery (described as *F. oxysporum* 96)
isolated in 1997:
Rhizoctonia solani from bed II, Kukawy nursery (described as *R. solani* 97)
Fusarium culmorum from bed VII, Kukawy nursery (described as *F. culmorum* 97)
F. oxysporum from bed VII, Kukawy nursery (described as *F. oxysporum* 97)
F. avenaceum (Fr.) Sacc., Grodziec nursery (described as *F. avenaceum* 97)

Fungal communities were isolated from soil samples from each bed with Warcup (1950) soil plate method modified by Mańka (Mańka 1964; Mańka and Salmanowicz 1987) and identified according to Gams, Anderson and Domsch (1980). Fifteen most frequently occurring species (components) of each community were chosen for biotic tests.

All the communities of soil fungi were tested for their effect on the growth of pathogenic fungi with the biotic series method by Mańka (Mańka 1974; Mańka and Mańka 1992; Mańka and Mańka 1995). After testing every species of each community against a damping-off pathogen, an individual biotic effect of the community component on the pathogen was obtained. The individual biotic effect (IBE) is the effect of one isolate of a given species on the growth of the pathogen. The IBE multiplied by the species frequency results in the general biotic effect (GBE), treated as the effect of all the component's isolates on the pathogen. After summarizing all the GBEs the summary biotic effect (SBE) is obtained, providing the effect

of the entire soil fungi community on the pathogen. The biotic effects may be: positive (indicating suppressive effect on the pathogen's growth), negative (indicating supporting effect on the pathogen's growth) or neutral ("0"), with the intensity of the effect described by its absolute value. The tests were performed on PDA medium prepared in the routine way (pH 5.6), acidified with HCl to pH 4.3 and adjusted with NaOH to pH 7.5. The pH was measured after autoclaving the medium. The results of the tests were evaluated after 10 days of incubation at 5, 10, 15, 20 and 25°C.

The data were evaluated by the analysis of variance and Duncan's multiple range test (STATISTICA version 5.0).

RESULTS

The results of soil pH analyses are shown in Table 1. The soils at the sites with similar rotation were also rather similar in their pH.

Table 1

Soil pH in the Garncarskibród and Kukawy nurseries and peat pH in Grodziec

pH	Garncarskibród		Kukawy		Grodziec
	bed IV	bed VI	bed II	bed VII	
pH in H_2O	6.45	5.70	7.00	5.20	5.5–6.5
pH in 1M KCl	5.85	5.17	6.80	4.60	no data

The results of the biotic test (values of SEB) are presented in Tables 2–6. Among the fungi (community components) with positive individual biotic effect on the growth of studied pathogens some examples were chosen and included in Table 7.

The influence of soil fungi communities on the growth of Rhizoctonia solani

The soil fungi communities originating from the Garncarskibród nursery suppressed the growth of *R. solani* (isolate *R. solani* 96) rarely and to a small degree (Table 2). The community from bed IV suppressed the growth of the pathogen only at 5°C and pH 5.6 (SEB = +12), and the community from bed VI suppressed it at the same temperature at pH 4.3 (SEB = +118), pH 5.6 (SEB = +106) and pH 7.5 (SEB = +28). At 10°C this community suppressed the growth of the pathogen only at pH 4.3 (SEB = +5). Both communities supported the growth of the pathogen at 10°C more at pH 5.6 and 7.5 than at pH 4.3. At 15, 20 and 25°C the community from bed IV supported the growth of the pathogen stronger at pH 7.5 as compared with pH 4.3 and 5.6. It turned out, that the supporting effect of the community from bed IV on the growth of *R. solani* 96 was 2–3 times stronger than the

supporting effect of the community from bed VI. The growth of *R. solani* 96 was suppressed by: *Gliocladium catenulatum*, *Stachybotrys chartarum*, *Trichoderma atroviride*, *T. koningii*, *T. viride*, *Truncatella truncata* and *Zygorrhynchus moelleri* (Table 8), which were not frequent enough in their communities to make the SBE positive.

In Kukawy only the community from bed II suppressed the growth of *R. solani* at 5°C and pH 4.3 (SEB = 33), pH 5.6 (SEB = +11) as well as at 10°C and pH 4.3 (SEB = +44) and pH 7.5 (SEB = +66); (Table 2). At 10°C the community from bed II supported the growth of the pathogen more at pH 5.6 than at pH 4.3 or 7.5; and at the same temperature the community from bed VII suppressed it more at pH 5.6 and 7.5 than at pH 7.5. The growth of *R. solani* 97 was suppressed by *T. atroviride*, *T. truncata* and *Z. moelleri*, originating from bed II. Among the species belonging to the community from bed VII no one suppressed the growth of the pathogen (Table 8).

Table 2

Summary biotic effect (SEB) of soil fungi communities on the growth of two *Rhizoctonia solani* isolates in relation to incubation temperature and medium pH

Medium pH	Temperature				
	5°C	10°C	15°C	20°C	25°C
R. solani 96					
bed IV Garncarskibród					
4,3	0 a*	−185 b	−1048 cd	−1226 d	−1224 d
5,6	+12 a	−776 c	−1052 d	−1204 c	−1396 d
7,5	0 a	−891 c	−1459 e	−1728 f	−1712 f
bed VI Garncarskibród					
4,3	+118 a	+5 a	−430 c	−457 c	−466 c
5,6	+106 a	−194 b	−398 c	−528 cd	−695 cd
7,5	+28 a	−352 b	−501 cd	−628 cd	−577 cd
R. solani 97					
bed II Kukawy					
4.3	+33 a	+44 a	−571 cd	−770 d	−901 de
5.6	+11 a	−100 b	−612 cd	−768 d	−877 d
7.5	0 a	+66 a	−345 c	−701 d	−837 d
bed VII Kukawy					
4.3	0 a	−41 b	−497 d	−596 d	−663 d
5.6	0 a	−47 b	−463 d	−562 d	−656 d
7.5	0 a	0 a	−209 c	−572 d	−666 d

* – means within lines and columns (the results relative to each bed) followed by the same letter do not differ significantly (P = 0.05) according to Duncan's multiple range test

The influence of soil fungi communities on the growth of *Fusarium avenaceum*

The communities from Kukawy suppressed the growth of the pathogen slightly only at 5°C – the community from bed II at pH 4.3 (SEB = +22), and the community from bed VII – at pH 5.6 (SEB = +18); (Table 3).

The suppressing species were only *Fusarium oxysporum*, *T. atroviride* and *Z. moelleri* (Table 8).

Table 3

Summary biotic effect (SEB) of soil fungi communities from the Kukawy nursery on the growth of *F. avenaceum* 97 in relation to incubation temperature and medium pH

Medium pH	Temperature				
	5°C	10°C	15°C	20°C	25°C
bed III					
4,3	+22 a	−6 ab	−263 cd	−318 cd	−341 cd
5,6	0 a	−105 b	−345 cd	−425 d	−477 de
7,5	0 a*	−3 ab	−328 cd	−489 de	−474 de
bed VII					
4,3	0 a	−18 ab	−202 c	−287 cd	−318 cd
5,6	+18 a	−20 ab	−266 c	−306 cd	−361 cd
7,5	0 a	−32 ab	−220 c	−320 cd	−390 cd

* – see Table 2

The influence of soil fungi communities on the growth of *Fusarium culmorum*

The growth of *F. culmorum* 96 was suppressed to a small degree at pH 4,3 by the community from bed IV, Garncarskibród nursery, at 5°C (SEB = +6) and 10°C (SEB = +26), and stronger by the community from bed VI – at 5°C (SEB = +68) and 10°C (SEB = +162). Additionally, the latter community suppressed the growth of the pathogen at pH 7.5 and 5°C (SEB = +12); (Table 4). The community isolated from bed IV, Garncarskibród nursery, supported the growth of the pathogen less at 10, 15 and 20°C and pH 4.3 as compared to pH 5.6 and 7.5 ($P < 0.05$). The community isolated from bed VI suppressed the growth of the pathogen stronger at 10°C and pH 4.3 as compared with pH 5.6 and 7.5; also, the community supported it stronger at 10, 20 and 25°C and pH 5.6 as compared to pH 4.3 and 7.5. It turned out that the support of both communities to *F. culmorum* 96 was weaker above 20°C, independently of pH (except the community from bed VI at pH 5.6). The species that supported the growth of the pathogen were: *F. oxysporum*, *F. solani*, *G. catenulatum*, *S. chartarum*, *T. atroviride*, *T. koningii*, *T. viride* and *Z. moelleri* (Table 8).

Table 4

Summary biotic effect (SEB) of soil fungi communities on the growth of two *F. culmorum* isolates in relation to incubation temperature and medium pH

Medium pH	Temperature				
	5°C	10°C	15°C	20°C	25°C
R. culmorum 96					
bed IV Garncarskibród					
4,3	+6 ab	+26 a	−399 d	−306 d	−271 d
5,6	0 ab*	−377 d	−568 e	−522 e	−374 d
7,5	0 ab	−189 c	−688 e	−597 e	−475 de
bed VI Garncarskibród					
4,3	+68 a	+162 a	−188 c	−201 c	−86 bc
5,6	0 ab	−249 cd	−231 cd	−377 d	−408 d
7,5	+12 ab	−53 bc	−121 c	−274 cd	−249 cd
F. culmorum 97					
bed II Kukawy					
4.3	+22 ab	0 ab	−124 c	−260 cd	−290 cd
5.6	0 ab	−105 c	−345 d	−408 d	−399 d
7.5	0 ab	+44 ab	−243 cd	−467 d	−300 d
bed VII Kukawy					
4.3	0 ab	−18 b	−176 c	−220 c	−232 cd
5.6	0 ab	−20 b	−266 cd	−283 cd	−258 cd
7.5	0 ab	−14 b	−197 c	−315 d	−268 cd

* – see Table 2

The community from bed II, Kukawy nursery, weakly suppressed the growth of *F. culmorum* (isolate *F. culmorum* 97) at 5°C and pH 4.3 (SEB = +22), and also at 10°C and pH 7.5 (SEB = +44); (Table 4). The growth of the pathogen at 5, 15 and 20°C was less supported at pH 4.3 as compared to pH 5.6 and 7.5. The effect of the community from bed VII, Kukawy nursery, on the growth of *F. culmorum* 97 at 5°C was neutral (SEB = +0). At higher temperatures the community supported the pathogen growth independently of pH. The growth of the pathogen at 15 and 20°C was less supported at pH 4.3 as compared to pH 5.6 and 7.5. The support of both communities to *F. culmorum* 97 was weaker above 20°C, independently of pH, like in the case of the communities from the Garncarskibród nursery.

The growth of *F. culmorum* 97 was suppressed by *Chaetomium globosum*, *F. oxysporum*, *F. solani*, *T. truncata*, *T. atroviride* and *Z. moelleri* (Table 8).

The influence of soil fungi communities on the growth of *Fusarium oxysporum*

The soil fungi community from bed IV, Garncarskibród nursery, suppressed the growth of *F. oxysporum* 96 at 5°C and pH 4.3 (SEB = +16), and also at 10°C and all tested pH values (Table 5). At 15°C the community supported the growth of the pathogen less at pH 5.6 as compared to pH 4.3 and 7.5, and at 25°C the community supported it more at pH 7.5 as compared to pH 4.3 and 5.6 ($P < 0.05$). The community from bed VI, Garncarskibród nursery, suppressed the growth of *F. oxysporum* 96 at 5°C and pH 4.3 (SEB = +118) as well as pH 7.5 (SEB = +42), similarly at 10°C and all tested pH values (Table 5). At 25°C the community supported the growth of the pathogen less at pH 4.3 as compared with pH 5.6 and 7.5 ($P < 0.05$); at 5 and 15°C the community suppressed it less at pH 5.6 as compared to pH 4.3 and 7,5. The support of both soil fungi communities to *F. oxysporum* 96 was weaker above 20°C at pH 4.3 as compared to pH 5.6 and 7.5.

The species suppressing the growth of *F. oxysporum* 96 were: *Ch. globosum*, *G. catenulatum*, *T. atroviride*, *T. koningii*, *T. viride*, *T. truncata* and *Z. moelleri* (Table 8).

Suppressing effects of soil fungi communities from the Kukawy nursery on the growth *F. oxysporum* 97 were very weak. The community from bed II suppressed it at 5°C and pH 4.3 (SEB = +44), at 10°C and pH 4.3 (SEB = +33) as well as pH 7.5 (SEB = +44); (Table 5). At 5 and 10°C this community supported the growth of the pathogen stronger at pH 5.6 as compared to pH 4.3 and 7.5. At 15°C the community supported it less at pH 7,5 as compared to 4.3 and 5.6 ($P < 0.05$). The soil fungi community from bed VII suppressed the growth of the pathogen slightly only at 10°C and pH 4.3 (SEB = +3). At 15°C the community supported the growth of the pathogen less at pH 7.5 as compared to pH 4.3 and 5.6 ($P < 0.05$).

The growth of *F. oxysporum* 97 was suppressed by *Ch. globosum*, *Penicillium janczewskii*, *T. truncata*, *T. atroviride* and *Z. moelleri* (Table 8).

The influence of soil fungi communities on the growth of *Fusarium solani*

The SEB of soil fungi communities from the Garncarskibród nursery on *F. solani* 96 growth at 5 and 10°C was neutral or suppresing, depending on medium pH (Table 6).

The community from bed IV suppressed the growth of the pathogen less at 5°C and pH 4.3 than at 10°C. At 15 and 20°C the community supported the growth of the pathogen less at pH 4.3 as compared to pH 5.6 and 7.5. The support of the growth of *F. solani* 96 above 20°C was weaker, independently of medium pH.

The community isolated from bed VI at all tested temperatures suppressed the growth of the pathogen more at pH 4.3 as compared to pH 5.6 and 7.5.

Table 5

Summary biotic effect (SEB) of soil fungi communities on the growth of two *F. oxysporum* isolates in relation to incubation temperature and medium pH

Medium pH	Temperature				
	5°C	10°C	15°C	20°C	25°C
R. oxysporum 96					
bed IV Garncarskibród nursery					
4,3	+12 ab	+42 a	−407 d	−651 d	−449 d
5,6	0 ab	+124 a	−264 c	−410 d	−522 d
7,5	0 ab	+23 ab	−460 d	−670 de	−750 d
bed VI Garncarskibród					
4,3	+118 a	+144 a	−165 c	−287 cd	−240 c
5,6	0 ab	+68 a	−277 cd	−451 d	−488 d
7,5	+42 a	−105 a	+112 bc	−463 d	−508 d
R. oxysporum 97					
bed II Kukawy nursery					
4.3	+44 a	+33 a	−167 c	−349 cd	−495 d
5.6	−33 b	−21 b	−201 c	−345 cd	−506 d
7.5	0 ab	+44 a	−110 b	−398 cd	−469 d
bed VII Kukawy nursery					
4.3	0 ab	+3 a	−154 c	−235 c	−338 d
5.6	0 ab	9 ab	−222 c	−293 cd	−366 d
7.5	0 ab	0 ab	−36 b	−277 cd	−344 d

* — see Table 2

Table 6

Summary biotic effect (SEB) of soil fungi communities from the Garncarskibród nursery on the growth of *F. solani* 96 in relation to incubation temperature and medium pH

Medium pH	Temperature				
	5°C	10°C	15°C	20°C	25°C
bed IV Garncarskibród nursery					
4.3	+23 ab	+37 ab	−399 d	−306 d	−255 cd
5.6	0 b	+3 ab	−568 de	−506 d	−342 d
7.5	0 b	+23 ab	−688 e	−597 de	−466 d
bed VI Garncarskibród nursery					
4.3	+118 a	+168 a	−165 cd	−264 d	−244 cd
5.6	0 b	+28 ab	−308 d	−410 d	−436 de
7.5	+28 ab	+112 a	−119 c	−428 de	−523 de

* — see Table 2

The growth of *F. solani* 96 was suppressed by *Ch. globosum*, *F. oxysporum*, *F. solani*, *G. catenulatum*, *T. atroviride*, *T. koningii*, *T. viride*, *T. truncata* and *Z. moelleri* (Table 8).

Table 7

In vitro effect of soil fungi communities on the growth of tested pathogens in relation to temerature and medium pH – the results of multiple analyses of variance

Pathogen + communities of soil fungi	Analyses of variance in dependence on*		Correlation coefficients in dependence on**	
	temperature	medium pH	temperature	medium pH
R. solani 96 + the community from bed IV of Garncarskibród nursery (tab. 3)	0.000226*	ns	0.92**	0.30
R. solani 96 + the community from bed VI of Garncarskibród nursery (tab. 3)	0.000059*	ns	0.94**	0.21
R. solani 97 + the community from bed II of Kukawy nursery (tab. 3)	0.000001*	ns	0.89**	0.09
R. solani 97 + the community from bed VII of Kukawy nursery (tab. 3)	0.000001*	ns	0.89**	0.11
F. avenaceum 97 + the community from bed II of Kukawy nursery (tab. 4)	0.000008*	ns	0.89**	0.15
F. avenaceum 97 + the community from bed VII of Kukawy nursery (tab. 4)	0.000001*	ns	0.91**	0.07
F. culmorum 96 + the community from bed IV of Garncarskibród nursery (tab. 5)	0.003609*	ns	0.73**	0.34
F. culmorum 96 + the community from bed VI of Garncarskibród nursery (tab. 5)	0.025942*	ns	0.78**	0.03
F. culmorum 97 + the community from bed II of Kukawy nursery (tab. 5)	0.000397*	ns	0.83**	0.12
F. culmorum 97 + the community from bed VII of Kukawy nursery (tab. 5)	0.000001*	ns	0.88**	0.09
F. oxysporum 96 + the community from bed IV of Garncarskibród nursery (tab. 6)	0.000039*	ns	0.82**	0.13
F. oxysporum 96 + the community from bed VI of Garncarskibród nursery (tab. 6)	0.000088*	ns	0.80**	0.16
F. oxysporum 97 + the community from bed II of Kukawy nursery (tab. 6)	0.000001*	ns	0.85**	0.01
F. oxysporum 97 + the community from bed VII of Kukawy nursery (tab. 6)	0.000006*	ns	0.85**	0.05
F. solani 96 + the community from bed IV of Garncarskibród nursery (tab. 7)	0.000098*	ns	0.71**	0.26
F. solani 96 + the community from bed VI of Garncarskibród nursery (tab. 7)	0.000178*	ns	0.80**	0.18

* – significant effect of factor indicated by $P < 0.05$; ** – correlation coeficients significant at $P < 0.05$; ns – not significant

Statistical analyses

The soil fungi communities originating from both nurseries supported in the majority of cases the growth of studied pathogenic fungi. It was confirmed that supporting effect increased together with the increase of temperature (5 to 25°C), independently of pH (4.3 to 7.5). The results of the analysis of variance indicate that this effect was very dependent on incubation temperature ($P < 0.05$) and not dependent on medium pH (Table 7).

Duncan's multiple range tests show no significant differences (in the majority of cases) in the effect of soil fungi communities on the *in vitro* growth of the pathogens tested between the temperatures 15, 20 and 25°C, independently of medium pH (Tables 2–6).

Table 8

Positive individual biotic effect (IBE) of some species of fungi on the growth of tested pathogens in relation to incubation temperature and medium pH

Community components (isolation site)	Frequency	Temperature [°C]	IBE at pH		
			4.3	5.6	7.5
***R. solani* 96**					
Trichoderma atroviride Bisset (bed IV, Garncarskibród nursery)	8	15	+5	+1	0
		20	+5	+7	+4
		25	+7	+7	+7
Zygorrhunchus moelleri Vuill. (bed VI, Garncarskibród nursery)	14	5	+7	+4	+2
		10	+3	+4	+3
		15	+2	+8	+3
		20	+4	+3	+4
***R. solani* 97**					
Trichoderma atroviride Bisset (bed II, Kukawy nursery)	3	10	0	+1	+6
		15	+8	+1	+7
		20	+8	+8	+7
		25	+8	+8	+7
***F. avenaceum* 97**					
Zygorrhunchus moelleri Vuill. (bed II, Kukawy nursery)	11	5	+2	0	0
		10	+2	+2	+3
		15	+4	+4	+4
		20	+5	+2	+3
		25	+7	+6	+5

Tab. 8 cont.

Community components (isolation site)	Frequency	Temperature [°C]	IBE at pH		
			4.3	5.6	7.5
***F. culmorum* 96**					
Fusarium oxysporum Schlecht. (bed IV, Garncarskibród nursery)	10	20	+2	0	+1
		25	+1	0	+2
Gliocladium catenulatum Gilm. et Abbott (bed VI, Garncarskibród nursery)	9	10	0	+1	0
		15	+5	+4	+4
		20	+7	+4	+7
		25	+7	+5	+7
***F. culmorum* 97**					
Trichoderma atroviride Bisset (bed II, Kukawy nursery)	3	15	+4	+5	+3
		20	+6	+6	+4
		25	+8	+7	+6
Chaetomium globosum Künze (bed VII, Kukawy nursery)	5	20	0	+1	+1
		25	0	+3	+4
***F. oxysporum* 96**					
Truncatella truncata (Lev.) Steyaert (bed IV, Garncarskibród nursery)	11	10	+1	0	+1
		15	+2	−1	+1
Gliocladium catenulatum Gilm. et Abbott (bed VI, Garncarskibród nursery)	9	15	+7	+3	+4
		20	+7	+4	+6
		25	+8	+4	+7
***F. oxysporum* 97**					
Trichoderma atroviride Bisset (bed II, Kukawy nursery)	3	15	+5	+5	+3
		20	+6	+7	+6
Truncatella truncata (Lev.) Steyaert (bed VII, Kukawy nursery)	3	25	+7	+8	+6
		10	+1	0	0
		15	+1	0	+1
***F. solani* 96**					
Fusarium oxysporum Schlecht. (bed IV, Garncarskibród nursery)	10	20	+2	0	+1
		25	+1	0	+2
Gliocladium catenulatum Gilm. et Abbott (bed VI, Garncarskibród nursery)	9	10	+1	0	0
		15	+7	+3	+4
		20	+7	+4	+6
		25	+	+3	+6

DISCUSSION

The results of biotic tests indicate that the soil fungi communities studied do not suppress (in the majority of cases) the growth of tested pathogenic fungi, independently of plant rotation. In the case of *R. solani*, the soil fungi communities from both Garncarskibród and Kukawy nurseries, isolated from the beds with the "first type" of rotation – recommended from the forest management point of view, suppressed the growth of this pathogen stronger. The supporting effect of communities on the growth of the pathogen was very high. The SBE values at 25°C were within the range −466 to −1712. On the contrary, the supporting effect of the communities studied on the growth of *Fusarium* spp. was not so strong. At 25°C the SBE values were ranged from −86 to −750. At lower temperatures (5, 10°C) the soil fungi communities, isolated from the beds with the "second type" of rotation, frequently less supported or even suppressed stronger the growth of tested *Fusarium* then the soil fungi communities, originating from the beds with the "first type" of rotation. However, it was observed that the types of rotation studied affected rather the qualitative and quantitative structure of soil fungal communities (Kacprzak and Mańka 2000) than the influence of the communities on the growth of the pathogens. It confirmes cosmopolitan character of the severe pathogens belonging to the genus *Fusarium* and *Rhizoctonia solani* (Gams et al. 1980).

It appeared in this study that the supporting effect of all the studied communities of soil fungi on the growth of tested pathogens was increasing with the increase of temperature (significant at $P < 0.05$). Similarly, temperature dependent antagonists – pathogen interactions have also been shown by Kwaśna (1987), Mukherjee and Raghu (1997). In the majority of cases SBE values were significantly different between those obtained at 5 and 10°C and those obtained at higher temperatures. However, the SBE values at 15, 20 and 25°C were not significantly different from each other. It seems that 15°C is a temperature limit, above which the growth of colonies is much more intensive, what influences the SBE value. Positive summary biotic effect, indicating suppressive effect on the pathogen's growth was observed only at lower temperatures (5, 10°C).

The influence of medium pH, within the range studied, on the effect of the communities on the growth of tested pathogens was not significant. It was connected with the growth intensity of pathogens and saprotrophs: the colony diameter of all the fungi increased with the increase of temperature (5 to 25°C), independently of pH (4.3 to 7.5) (Kacprzak and Mańka 2000). Frużyńska-Jóźwiak and Mańka (1994) reported that the individual biotic effect of two *Trichoderma* spp. and three *Penicillium* spp. on the growth of *Fusarium oxysporum* f.sp. *dianthi* was influenced neither by PDA medium pH changing from 6.5 to 4.0 nor by incubation at temperatures within the range +10 to +35°C. However, in this study, it was

observed that the IBE of the majority of fungi belonging to the *Trichoderma* genus increased together with increasing temperature from 0 (at 5°C), through +2, +4 (at 10°C) to +7, +9 (at 25°C).

As mentioned above, temperature significantly modified the summary biotic effect of soil fungi communities on the *in vitro* growth of the pathogenic fungi tested. The individual biotic effect (absolute value) increased with increasing temperature. The growth of pathogenic fungi was suppressed to a high degree by: *Gliocladium catenulatum*, *Trichoderma atroviride*, *T. koningii*, *T. viride* and *Zygorrhynchus moelleri*. Their positive IBE values increased with increasing temperature, independently of pH. This confirms a great role, which antagonistic fungi species may play in the soil environment of plants, on condition that their frequency is high enough. The antagonistic effect increasing in acidic soils was described in the case of *Trichoderma lignorum* by Weindling and Fawcett (1936) and *Penicillium* by Newsham et al. (1995). In our study the dependence was not observed.

The results indicate that medium pH (within the range studied) has no influence either on the growth of the pathogens tested and the components of soil fungi communities, or on the effect of soil fungi communities on the growth of pathogens. However, temperature had significant effect both on the growth rates and interactions between saprotrophs and pathogens. The supporting effect of fungal communities on the pathogens' growth, increasing with an increase of temperature, could partially explain stronger development of damping-off disease at higher temperatures (20/25°C) as compared to lower ones (10/15°C) described by Kacprzak et al. (in print).

REFERENCES

Bandoni R. J. 1979: Safranin O as a rapid nuclear stain for fungi. Mycologia 71: 873–875.

Frużyńska-Jóźwiak D., Mańka M. 1994: Biotic series method for evaluation of soil fungi effect on plant pathogenic fungi. II. Effect of medium pH, medium amendments and temperature on individual biotic effect value. Phytopathol. Pol. 7 (XIX): 131–136.

Gams W., Anderson T. H., Domsch W. 1980: Compendium of soil fungi. Academic Press (London) Ltd.

Garrett S. D. 1965: Toward biological control of soil-borne pathogens. In: K. F. Baker, W. C. Snyder (eds.) Ecology of soil-borne plant pathogens. Univ. California Press, Berkeley – Los Angeles: 4–17.

Gierczak M. 1972: Zbiorowiska grzybów glebowych i ściółkowych w niektórych roślinnych zespołach Puszczy Bukowej pod Szczecinem. Prace Kom. Nauk Roln. i Kom. Nauk Leśn. PTPN 34: 13–59.

Gierczak M., Mańka K., Przezbórski A. 1987: Zbiorowiska grzybów wyizolowanych z chorych siewek sosny zwyczajnej z dziesięciu szkółek leśnych w województwie poznańskim. Zesz. Probl. Post. Nauk Rol. 307: 69–80.

Kacprzak M., Mańka M. 2001. Influence of plant rotation on the structure of soil fungal communities from under Scots pine seedlings in forest nurseries. Bulletin IOBC, in print.

Kacprzak M., Mańka M. 2001. Effect of incubation temperature and medium pH on the growth of the pathogenic and saprotrophic soil fungi from forest nurseries. Phytopathol. Pol.

Kacprzak M., Asiegbu F. O., Daniel G., Stenlid J., Mańka M., Johansson M.: Differential resistance of conifer species (Norway spruce, Scots pine, Larch) to infection by necrotrophic damping off pathogens. European J. Plant Pathol., in print.

Kwaśna H. 1987: Badanie niektórych właściwości saprofitycznych grzybów glebowych jako ewentualnych składników biopreparatów do ochrony siewek sosny przed pasozytniczą zgorzelą siewek. Rocz. Nauk Rol. s. E 17 (2): 135–149.

Kwaśna H., Chełkowski J., Zajkowski P. 1991. Flora Polska. Grzyby (*Mycota*), 22. PAN Instytut Botaniki. Warszawa–Kraków.

Magan N., Lacey J. 1984: Effect of water activity, temperature and substarte on interactions between field and storage fungi. Trans. Br. Mycol. Soc.: 85: 83–93.

Mańka K. 1964: Próby dalszego udoskonalenia zmodyfikowanej metody Warcupa izolowania grzybów z gleby. Prace Kom. Nauk Roln. i Kom. Nauk Leśn. PTPN, 17: 29–43.

Mańka K. 1974: Zbiorowiska grzybów jako kryterium oceny wpływu środowiska na choroby roślin. Zesz. Probl. Post. Nauk Roln. 160: 9–23.

Mańka K. 1998: Fitopatologia Leśna. V ed. PWRiL. Warszawa.

Mańka K., Mańka M. 1992: A new method for evaluating interaction between soil inhabiting fungi and plant pathogens. IOBC/WPRS Bulletin 15 (1): 73–75.

Mańka K., Salmanowicz B. 1987: Udoskonalenie niektórych technik zmodyfikowanej metody płytek glebowych do izolowania grzybów z gleby z punktu widzenia potrzeb mikologii fitopatologicznej. Roczn. Nauk Rol. s. E 17 (1): 35–46.

Mańka M. 1995: Non-pathogenic soil fungi reflecting soil environment. In: M. Mańka (ed.). Environmental Biotic Factors In Integrated Plant Disease Control, Proceedings of 3rd Conference of European Foundation for Plant Pathology, 5–9.09.1994 Poznań: 27–36.

Mańka M., Mańka K. 1995: Biotic series method for evaluation of soil fungi effect on plant pathogenic fungi. III. Measurement of inhibition zone between test fungus and tested fungus in biotic test. Phytopathol. Pol. 10 (22): 99–105.

Mikołajska J., Wachowska U. 1996: Charakterystyka dwujądrowych izolatów z rodzaju *Rhizoctonia* uzyskanych ze zbóż w Polsce północno-wschodniej. In: M. Kowalik, S. Kowalski (eds.). „Nowe kierunki w fitopatologii". Materiały z sympozjum. 11–13.09.1996. Kraków. PTFit., Oddział w Krakowie, Kraków: 303–307.

Mukherjee K., Raghu K. 1997: Effect of temperature on antagonistic and biocontrol potential of *Trichoderma* sp. on *Sclerotium rolfsii*. Mycopathologia 139: 151–155.

Newsham K. K., Watkinson A. R., Fitter A. H. 1995: Rhizosphere and root infecting fungi and the design of ecological field experiments. Oecologia 102: 230–237.

Strzelczyk E. 1988: Biologiczne zwalczanie roślinnych patogenów glebowych. Postępy Mikrobiologii 27 (3): 255–272.

Warcup J. H. 1950. The soil plate method for isolation of fungi from soil. Nature: 166, 117–118.

Weindling R., Fawcett H. S. 1936: Experiments in the control of Rhizoctonia damping-off of citrus seedlings. Hilgardia 10: 1–6.

Wpływ temperatury inkubacji i odczynu pożywki na oddziaływanie zbiorowisk grzybów glebowych na wzrost patogenów zgorzelowych

Streszczenie

Badano wpływ temperatury inkubacji (5, 10, 15, 20 i 25°C) i odczynu pożywki (4,3; 5,6; 7,5) na oddziaływanie *in vitro* czterech zbiorowisk grzybów glebowych ze szkółek leśnych na wzrost patogenów zgorzelowych (*Rhizoctonia solani, Fusarium avenaceum, F. culmorum, F. oxysporum* i *F. solani*).

Badane zbiorowiska grzybów glebowych tylko w niższych temperaturach słabo ograniczały wzrost testowanych patogenów. W wyższych temperaturach zbiorowiska sprzyjały wzrostowi patogenów. Sprzyjający wpływ zbiorowisk na wzrost patogenów wzrastał wraz ze wzrostem temperatury, niezależnie od odczynu pożywki. Wyniki analizy wariancji wskazują, że wpływ ten jest zależny od temperatury ($P < 0,05$), lecz nie od odczynu pożywki.

Wyniki testu Duncana wskazują, że wpływ zbiorowisk grzybów glebowych na wzrost badanych patogenów nie różnił się na poziomie statystycznym (dla większości przypadków) między temperaturami 15, 20 i 25°C, niezależnie od odczynu pożywki.

Spośród saprotroficznych grzybów glebowych wzrost badanych patogenów ograniczały: *Gliocladium catenulatum*, *Trichoderma atroviride*, *T. koningii*, *T. viride*, *Truncatella truncata* i *Zygorrhynchus moelleri*.