ヒエ(Echinochloa)属病原菌のExserohilum monocerasによるイネ葉いもちの生物学的防除

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Biological Control of Rice Leaf Blast with *Exserohilum monoceras*, a Pathogen of *Echinochloa* Species

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Abstract

Pre-inoculation with a suspension of 10^6 conidia/ml of *Exserohilum monoceras*, a pathogen of *Echinochloa* species, within the 7 days prior to challenge inoculation with *Pyricularia oryzae*, reduced the number of rice blast lesions in the greenhouse, regardless of rice variety. In the field, a single foliar application of a conidial suspension of *E. monoceras* reduced lesions on leaves by more than 85% in the 2 to 6 weeks after application. Blast on non-inoculated leaves in these plots was also suppressed. The result suggests that inhibition of primary blast development by the application will reduce the chance of new infections to upper leaves, although *E. monoceras* did not induce systemic host resistance in the greenhouse test. Double, triple and quadruple applications with a week between applications, produced the same results. Transplanting *E. oryzicola* plants with disease caused by *E. monoceras* between rice hill rows in paddy fields, also suppressed blast, suggesting that conidia from lesions on diseased *E. oryzicola* plants may be dispersed to rice plants and suppress blast. Moreover, the effect of the application of *E. monoceras* on rice growth and yield was examined in a paddy field and compared with that of commonly used chemical fungicides. Single and double applications did not affect plant culm length, panicle length, panicle number, plant dry weight or grain yield, whereas triple applications reduced culm length, and the quadruple application reduced culm length, plant dry weight and grain yield. Provided that it is not applied more twice, *E. monoceras* is a promising biological agent for the control of rice blast with no adverse effects on rice growth and grain yield.

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Key words: biological control, *Exserohilum monoceras*, rice leaf blast.

INTRODUCTION

Biological control of plant disease using microorganisms has been studied by many researchers. Biological control depends on four mechanisms for suppression[3]: direct antagonism, such as competition between microorganisms for nutrients or for infection sites on plants[4,5]; an induced or enhanced resistance caused by incompatible races or nonpathogens[23]; antibiotic substances or enzymes produced by microorganisms[12,21]; and hyperparasitism of plant pathogens[2,13,14]. Moreover, some biological control agents use a combination of these mechanisms[8,15] or unidentified mechanisms such as that shown in endophytes[16].

In rice blast disease, an incompatible race of *Pyricularia oryzae* and the non-pathogenic *P. grisea* induce host resistance accompanied by R-type lesions and degenerated cells, respectively, and suppress the disease[1,18]. As necrotic spots caused by the hypersensitive reaction (HR) become more severe, rice plants become more resistant to a compatible race of P. oryzae[6]. Another method of suppression is the production of an antiblast substance-producing by *Pseudomonas fluorescens*[9].

We found that *Exserohilum monoceras* induced fine spots similar to those observed in the HR on rice plants during a study of the biological control of a paddy weed, *Echinochloa* spp., using the fungus[19,20]. Accordingly, we investigated whether *E. monoceras* could control rice blast. In this paper, we report the reduction of the number of blast lesions after inoculation with *E. monoceras* in the greenhouse and paddy field. We also describe the effect of *E. monoceras* on rice growth and yield in the field.

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MATERIALS AND METHODS

Fungal isolates and inocula *Pyricularia oryzae* 1104-3 (race 013[22]) and HF93-102a (race 001), kindly provided by T. Namai and Y. Fujita, respectively, and *Exserohilum monoceras* B-026 were used in this study. *E. monoceras* B-026 was isolated from a diseased *Echinochloa oryzicola* plant collected in a paddy field. The fungus was pathogenic to *Echinochloa* species. *P. oryzae* was incubated on an oatmeal sucrose agar (OMSA) plate[19] at 25°C in the dark for 2 weeks. The plates were flooded with sterile distilled water, aerial mycelia were scraped off by brushing the surface of the colony, and the water was drained. After the plate surface had dried, it was incubated in the light (*ca.* 7000 lx) for 3 days. *E. monoceras* was incubated on an OMSA plate at 25°C in the dark for 3 weeks[19]. Conidia of the three fungal isolates were harvested with 0.02% Tween 20, and conidial density was measured with a haemacytometer (Thoma for *P. oryzae*, Fuchs-Rosenthal for *E. monoceras*, Kayagaki Irikakogyo, Japan).

Test plants Seeds of rice (*Oryza sativa* cvs. Sasanishiki and Koshihikari) were immersed at 30°C in the dark overnight in a solution of 0.5% (w/v) benomyl. They were then incubated in tap water at 30°C in the dark for 2 days. Germinated seeds were transplanted into a seedling box filled with granular soil (Kumiai-ryujoubaido-D, Kureha Chemicals, Japan). They were grown to the 5 th leaf stage (5-LS) in a greenhouse at 25/22°C (daytime/night). Seedlings were fertilized with 1% (w/v) ammonium sulfate solution approximately 10 days before inoculation with *P. oryzae* race 013, which is compatible with the two cultivars.

Inoculations and evaluation Rice plants at the 5-LS were preinoculated with 1.5 ml/100 cm^2 of a conidial suspension at a suitable density of *E. monoceras* B-026 with an airbrush sprayer (Gunpiece Rich GP-2, Fuso Seiki Co., Ltd., Japan). The inoculated plants were incubated in a darkened dew chamber at 25°C for 18 hr and then transferred to the greenhouse. One, 2, 3 or 7 days after pre-inoculation, the plants were challenge inoculated with a conidial suspension of *P. oryzae* race 013 (10^5 conidia/ml, 1.5 ml/100 cm^2). The inoculated plants were incubated in the dew chamber for 18 hr and then transferred to the greenhouse. Disease control was evaluated by counting the number of blast lesions on the 5 th leaf at 8 or 9 days after inoculation with *P. oryzae*.

Field plots The field trial was performed at Miyagi Prefectural Agricultural Research Center, at Natori city, Miyagi Prefecture, in 1994. Rice seedlings of cv. Sasanishiki were transplanted on May 6. The tests consisted of the following eight treatments: a single application of a conidial suspension (5×10^5 conidia/ml, 800 ml/4 m^2) of *E. monoceras* B-026 (July 6); two applications (July 6 and 12); three applications (July 6, 12 and 19); four applications (July 6, 12, 19 and 26); transplanting diseased *Echinochloa oryzicola* C type; four applications of a conidial suspension (2×10^5 conidia/ml, 800 ml/4 m^2) of incompatible race of *P. oryzae* (race 001) (July 6, 12, 19 and 26) as a positive control; applications of a solution (600 ml/4 m^2) of 0.02% fthalide (July 11) and 0.0012% kasugamycin plus 0.015% fthalide (July 21); or no treatment. The treatment areas were arranged in a randomized design with three plot replications per treatment. Each plot had 10 rows of 18 hills/row and was *ca.* 270 cm×280 cm. The area of application in each plot consisted of six rows of 14 hills/row in the center of the plot, *ca.* 200 cm×200 cm. The plants had grown to the 9-, 10-, 11- and 12-LS (flag leaf stage) by July 6, 12 , 19 and 26, respectively. Leaf blast occurred naturally.

Field applications The inoculum, a conidial suspension of either *E. monoceras* or *P. oryzae* incompatible race in water which had been autoclaved with 0.02% Tween 20 and 0.1% agar, was sprayed onto rice plants in the late evening. The agar keeps the conidia suspended in the water until application; otherwise, conidia sink immediately.

Echinochloa oryzicola plants suffering disease caused by *E. monoceras* B-026 were prepared. Plants at the 6- to 9-LS (*ca.* 50 to 80 cm in grass length) were inoculated with a conidial suspension (10^5 conidia/ml) of *E. monoceras* B-026 and then incubated in the dew chamber for 24 hr and transferred to the greenhouse. Five days after inoculation, plants were transplanted in pairs into one row of 14 pairs between the two central hill rows in the appropriate application areas on July 5. As almost all transplanted plants were dead by July 27, more plants were transplanted on July 27.

Field evaluations All blast lesions on leaves of whole plants were counted in 30 hills/plot on July 5, 13, 20, 27, August 4 and 17. In the *E. oryzicola* treatment, 20 hills on both sides of the row of transplanted, diseased *E. oryzicola* plants were evaluated. On August 17, only the four upper leaves of plants were evaluated. The number of panicles/hill was examined in 30 hills/plot on August 23. The tallest plants in 15 hills/plot were examined for culm and panicle length on August 24. Plants (50 hills/plot) were harvested on September 20 and 21, then plant weights with panicles and grain yield (whole paddy, winnowed paddy, hulled rice and hulled rice over 1.8 mm in length) were evaluated after air-drying in the usual manner.

RESULTS

Spots on rice caused by Exserohilum monoceras

Exserohilum monoceras induced fine spots on rice leaves. The blurred spots were visible 2 days after inoculation. At 7 days, the spots became distinct and had enlarged to approximately 0.5 mm (Fig. 1). At 14 days, the number and size of spots remained almost unchanged compared with at 7 days.

Suppression of blast lesions in greenhouse test

Pre-inoculation of *E. monoceras* at 10^5 and 10^6 conidia/ml significantly decreased the number of blast

Table 1. Effect of conidial density of *Exserohilum monoceras* on reduction of rice leaf blast lesions in the greenhouse

Conidial density (conidia/ml)	Sasanishiki		Koshihikari	
	Number of lesions[a)]	% control[b)]	Number of lesions	% control
0	21.9	—	35.3	—
10^4	17.1	22.0	22.3	36.7
10^5	13.0*[c)]	40.5	15.1*	57.3
10^6	5.1*	76.8	8.2*	76.9

a) Means on 15 leaves, the fifth leaf of plants, 8 days after challenge inoculation with a conidial suspension of a compatible race (*Pyricularia oryzae* race 013) 1 day after pre-inoculation with a conidial suspension of *E. monoceras* B-026.
b) Based on the number of lesions/leaf compared to the negative control in each column.
c) Means with an asterisk within each column are significantly different from those of the negative control (no conidia) according to Dunnett's test ($p=0.01$).

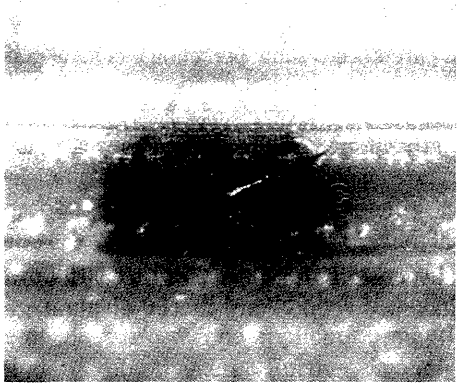

Fig. 1. Spots on rice leaf caused by *Exserohilum monoceras* B-026. A conidium (c) germinates and forms a tube (t) and induces a brown spot on a rice leaf 7 days after inoculation with a conidial suspension of *E. monoceras*.

lesions, regardless of the cultivar, compared with the control without conidia (Table 1). As the conidial density of *E. monoceras* increased, blast lesions decreased.

With time lags of 1, 2, 3 and 7 days before the challenge inoculation, the pre-inoculation of *E. monoceras* significantly reduced the number of lesions compared with the control (Table 2).

Suppression of blast lesions in field test

The first blast lesion was found in the external application area on July 5. Single and multiple applications of a conidial suspension of *E. monoceras* significantly reduced the number of blast lesions compared with no treatment, by July 20, 27, August 4 and 17 (Table 3). The number of blast lesions caused by the single and multiple applications, however, did not differ significantly (Table 3). The percentage control was more than 90% between July 27 and August 17 regardless of the number of applications of *E. monoceras*. In *E. monoceras* application plots, blast on untreated leaves was suppressed, *i.e.*, although conidia did not adhere to the 10 th and 11 th leaves in the single application, the number of lesions was significantly reduced to 8.0% and 11.5%, respectively, compared with the untreated control (Table 4). The 11 th and 12 th leaves in the double application and the 12 th leaves in the triple application gave the same result (Table 4).

Table 2. Reduction in blast lesions on rice plant cv. Sasanishiki after pre-inoculation of *Exserohilum monoceras* in the greenhouse

Time lag of two inoculations (days)[a)]	Number of lesions[b)]		% control
	Tw[c)]	Em[d)]	
1	22.3	8.5*[e)]	61.8
2	17.1	4.1*	76.2
3	13.7	6.9*	50.0
7	9.4	2.7*	71.0

a) Number of days between pre-inoculation and challenge inoculation.
b) Mean number of blast lesions/leaf at the 5-leaf stage (15 leaves), 9 days after challenge with compatible race 013.
c) 0.02% Tween 20 was applied before challenge with *Pyricularia oryzae* race 013.
d) Pre-inoculation with *E. monoceras* B-026 at 10^6 conidia/ml before challenge with *P. oryzae* race 013.
e) Means with an asterisk within each row are significantly different from those of treatments with Tween 20 solution (no-conidia treatments) according to Student's *t*-test ($p=0.01$).

Transplanting the *E. monoceras*-affected *E. oryzicola* and quadruple applications of incompatible race 001 of *P. oryzae* as a positive control, also significantly reduced blast lesions at comparable rates (about 70% control) by August 4 and 17 (Table 3). Chemical fungicides gave about 80% control. This comparatively low activity was probably due to a delay in application because of rain.

In the untreated plants, blast lesions reached a maximum on July 20 and then reduced gradually (Table 3), because lower rice leaves were withering and dying.

Influence of E. monoceras on rice growth and yield in field

There were no significant differences in culm length, panicle length, the number of panicles/hill, air-dried plant mass, whole paddy, winnowed paddy, hulled rice and hulled rice over 1.8 mm in length between the single and double applications of a conidial suspension of *E. monoceras* and the application of chemical fungicides as a control (Table 5). However, the triple application significantly reduced culm length to 97.2% of that in the control. Four applications also significantly reduced culm length to 92.8%, as well as dried plant to 86.1%,

Table 3. Suppression of blast lesions after application with conidia of *Exserohilum monoceras* in paddy field

Treatment[a)]	Number of blast lesions/30 hills and percentage control[b)]					
	July 5[c)]	July 13	July 20	July 27	Aug 4	Aug 17
1	0.0	16.3 a[d)] (57.8)	35.3 a (89.3)	17.0 a (94.2)	12.7 a (93.1)	11.0 a (92.8)
2	0.0	20.3 a (47.4)	25.3 a (92.3)	13.3 a (95.4)	9.3 a (94.9)	8.3 a (94.6)
3	0.0	21.0 a (45.7)	36.3 a (89.0)	10.0 a (96.6)	2.7 a (98.6)	3.3 a (97.8)
4	0.0	8.7 a (77.6)	15.0 a (95.5)	1.3 a (99.5)	1.7 a (99.1)	2.0 a (98.7)
Eo[e)]	0.0	22.0 a (43.1)	160.0 ab (51.7)	101.0 ab (65.4)	60.0 a (67.4)	42.0 a (72.6)
Po	0.0	30.0 a (22.4)	155.3 ab (53.1)	105.0 ab (64.0)	47.3 a (74.3)	41.0 a (73.3)
CF	0.0	35.3 a (8.6)	94.3 a (71.5)	61.0 a (79.1)	26.3 a (85.7)	24.3 a (84.1)
No treatment	0.0	38.7 a	331.0 b	291.7 b	184.0 b	153.3 b

a) Abbreviations: 1, one application of a conidial suspension of *E. monoceras* on July 6; 2, two applications on July 6 and 12; 3, three applications on July 6, 12 and 19; 4, four applications on July 6, 12, 19 and 26; Eo, transplanting *E. monoceras*-caused diseased *Echinochloa oryzicola* plants; Po, four applications of incompatible race 001 of *Pyricularia oryzae* on July 6, 12, 19 and 26; CF, applications of fthalide on July 11 and kasugamycin plus fthalide on July 21.
b) Means number of blast lesions/30 hills from triplicate plots. Values in parentheses show percentage control compared to no treatment in each column.
c) Day on which the blast lesions were counted.
d) Means followed by the same letter within each column are not significantly different according to Tukey-Kramer test ($p=0.05$).
e) The number of blast lesions/20 hills was extrapolated to 30 hills.

Table 4. Suppression of blast lesions on non-inoculated upper leaves after application of conidia of *Exserohilum monoceras*

Treatment[a)]	Number of blast lesions in each leaf/30 hills[b)]			
	12th[c)]	11th	10th	9th
1	0.7 ab[d)]	1.3 a	3.0 a	6.0 a
2	0.0 a	0.3 a	1.7 a	6.3 a
3	0.0 a	0.7 a	1.0 a	1.7 a
4	0.3 ab	0.3 a	0.3 a	1.0 a
Eo[e)]	0.5 ab	3.5 a	9.5 a	28.5 a
Po	0.3 ab	3.0 a	7.0 a	30.7 a
CF	0.0 a	0.0 a	6.3 a	18.0 a
No treatment	2.3 b	11.3 b	37.7 b	102.0 b

a) Abbreviations: 1, one application of a conidial suspension of *E. monoceras* on July 6; 2, two applications on July 6 and 12; 3, three applications on July 6, 12 and 19; 4, four applications on July 6, 12, 19 and 26; Eo, transplanting *E. monoceras*-caused diseased *Echinochloa oryzicola* plants; Po, four applications of incompatible race 001 of *Pyricularia oryzae* on July 6, 12, 19 and 26; CF, applications of fthalide on July 11 and kasugamycin plus fthalide on July 21. The rice plants grew to the 9-, 10-, 11- and 12-LS (flag leaf stage) on July 6, 12, 19 and 26, respectively.
b) Means number of blast lesions/30 hills from triplicate plots on August 17.
c) Twelfth leaf was the flag leaf.
d) Means followed by the same letter within each column are not significantly different according to Tukey-Kramer test ($p=0.05$).
e) The number of blast lesions/20 hills extrapolated 30 hills.

whole paddy to 83.3%, winnowed paddy to 84.4%, hulled rice to 84.8% and hulled rice over 1.8 mm in length to 83.7% of the control (Table 5). Four applications of a conidial suspension of *P. oryzae* of race 001, however, did not significantly reduce any factor of plant growth or yield (Table 5).

DISCUSSION

Biological control of plant disease using a weed pathogen is beneficial because the pathogen is not likely to damage useful plants while controlling the target weed. We demonstrated that *E. monoceras*, a mycoherbicidal agent for paddy weeds of *Echinochloa* spp.[19,20], could also suppress formation of rice leaf blast lesions on rice leaves in the greenhouse and paddy fields. In addition, we proved that one or two applications of *E. monoceras* did not affect rice growth and yield.

In the greenhouse, 10^6 conidia/ml was required to reduce the number of blast lesions (Table 1). Moreover, blast lesions were suppressed after pre-inoculation with *E. monoceras* within the 7 days before the challenge inoculation with *P. oryzae* (Table 2). However, suppression of blast was restricted to leaves that had been inoculated with *E. monoceras* (data not shown), similar to the case with an incompatible race of *P. oryzae*[11]. These results suggest that all new leaves may need to be sprayed with a conidial suspension of *E. monoceras* to control the disease. As a new leaf finishes developing in approximately a week, we estimated that the conidial suspension would need to be applied to new leaves every week in the paddy field trial after the first lesion appearance. However, only one application was required to suppress the disease by August 17 (6 weeks after application) (Table 3). Moreover, on leaves above those treated with *E. monoceras*, lesions were also reduced (Table 4). These results showed that inhibition of primary blast development by the first application will reduce new infections on the upper leaves. Without any pre-in-

Table 5. Effect of foliar application of *Exserohilum monoceras* on plant growth and yield

Treatment[a]	Culm length (cm)[b]	Panicle length (cm)[b]	Panicles number/hill[c]	Dried plant (kg)[d]	Whole paddy (kg)[d]	Winnowed paddy (kg)[d]	Hulled rice (kg)[d]	>1.8 mm-hulled rice (kg)[d]
1	80.9	16.8	23.7	3.37	1.87	1.80	1.46	1.41
2	80.7	16.5	24.9	3.46	1.86	1.82	1.45	1.40
3	78.6*[e]	16.4	25.3	3.23	1.71	1.68	1.34	1.30
4	75.1*	16.5	23.1	2.92*	1.55*	1.52*	1.23*	1.18*
Po	80.8	17.0	25.1	3.50	1.89	1.84	1.49	1.42
CF	80.9	17.0	23.5	3.39	1.86	1.80	1.45	1.41

a) Abbreviations: 1, one application of a conidial suspension of *E. monoceras* on July 6; 2, two applications on July 6 and 12; 3, three applications on July 6, 12 and 19; 4, four applications on July 6, 12, 19 and 26; Po, four applications of *Pyricularia oryzae* incompatible race (race 001) on July 6, 12, 19 and 26; CF, applications of the chemical fungicides fthalide on July 11 and kasugamycin plus fthalide on July 21.

b) Means of 45 hills (15 hills/plot, triplicate), the culm or panicle length of the tallest plant in a hill.

c) Means of 90 hills (30 hills/plot, triplicate), the number of panicles per hill.

d) Means of triplicate plots, the plant mass or yield factor from 50 hills in a plot.

e) Means with an asterisk within each column are significantly different from those of the CF control treatment according to Dunnett's test ($p=0.05$).

oculation, blast lesions declined gradually after the highest blast development on July 20 (Table 3), because secondary infections of the upper leaf seemed to be low, and the lower diseased leaves had died. Hence, when the incidence of blast is low, one application may lead to a long period of effectiveness. Further investigation is needed to examine the suppression of blast when disease incidence is high.

Transplanting *E. oryzicola* plants diseased by *E. monoceras* suppressed blast. In the same way, transplanting rice plants with disease caused by a compatible race of *P. oryzae* can protect other rice plant cultivars against their own compatible races of *P. oryzae*, if the conidia produced on the transplanted rice are incompatible with the cultivars needing protection[10,11]. The result suggests that conidia of *E. monoceras* which form on diseased plants, are dispersed to rice plants and protect them against the blast. The method, however, was the least effective (Table 3), so it has potential but may not be practical.

As the b-type spots (brown spots) caused by *P. oryzae* race 001 were fewer than those caused by *E. monoceras* in the field test, the application of *P. oryzae* race 001 may give lower control than that of *E. monoceras* (Table 3). With incompatible races of *P. oryzae*, suppression increases according to the type of spots shown, from the weakest, the HR type (cell death but no visible symptoms), through the b type to the strongest, the bg type (small eyespots with brown margins)[6]. Moreover, this is also the case with rice plant pathogens such as *Helminthosporium oryzae*, *Alternaria* sp. and *Curvularia* sp.: if their virulence is high, strong suppression is shown[7]. The spots caused by *E. monoceras* seem to be related to suppression of the blast. In fact, *E. monoceras* causes the same type of spots (Fig. 1) as the b-type spots caused by the incompatible race of *P. oryzae*. The fungus may suppress blast by inducing host resistance which is accompanied by spots resulting from degenerated cells as in the reaction to an incompatible race of *P. oryzae* or the non-pathogenic *P. grisea*[1,18].

Evaluating the effect of a phytopathogen on rice is essential when trying to control rice blast with the pathogen in paddy fields. *E. monoceras* did not reduce rice growth and grain yield after single or double applications, whereas triple applications reduced culm length and quadruple applications reduced culm length, plant mass and yield factors (Table 5). Excessive spots caused by *E. monoceras* are thought to affect plant activity and rice yield. The results indicate that *E. monoceras* can be applied twice to paddy fields without adverse affects to the rice plants. Moreover, unlike incompatible races of *P. oryzae*[11,17], *E. monoceras* will not mutate into compatible races nor infect compatible varieties of rice in neighboring fields. However, we must further investigate the effects of environmental factors, such as temperature, dew duration and rainfall, on plant growth and yield and suppression of the disease after application of the fungus, before practical use of the agent.

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Literature cited

1. Arase, S. and Fujita, K. (1992). Induction of inaccessibility to *Pyricularia oryzae* by pre-inoculation of *P. grisea* in rice leaf-sheath cells. J. Phytopathol. 134: 97-102.
2. Askary, H., Benhamou, N. and Brodeur, J. (1997). Ultrastructural and cytochemical investigations of the antagonistic effect of *Verticillium lecanii* on cucumber powdery mildew. Phytopathology 87: 359-368.

3. Blakeman, J.P. and Fokkema, N.J. (1982). Potential for biological control of plant diseases on the phylloplane. Annu. Rev. Phytopathol. 20 : 167-192.
4. Brodie, I.D.S. and Blakeman, J.P. (1975). Competition for carbon compounds by a leaf surface bacterium and conidia of *Botrytis cinerea*. Physiol. Plant Pathol. 6 : 125-135.
5. Fokkema, N.J. (1984). Competition for endogenous and exogenous nutrients between *Sporobolomyces roseus* and *Cochliobolus sativus*. Can. J. Bot. 62 : 2463-2468.
6. Fujita, Y., Sonoda, R. and Yaegashi, H. (1990). Leaf blast suppression by pre-inoculation of some incompatible lesion-type isolates of *Pyricularia oryzae*. Ann. Phytopathol. Soc. Jpn. 56 : 273-275 (in Japanese with English summary).
7. Fujita, Y. and Suzuki, H. (1979). Suppression of blast disease occurrence by double inoculation between rice blast fungus and some fungi on the rice plant. Annu. Rept. Plant Prot. North Japan 30 : 53-55 (in Japanese).
8. Furuya, N., Yamasaki, S., Nishioka, M., Shiraishi, I., Iiyama, K. and Matsuyama, N. (1997). Antimicrobial activities of Pseudomonads against plant pathogenic organisms and efficacy of *Pseudomonas aeruginosa* ATTC7700 against bacterial wilt of tomato. Ann. Phytopathol. Soc. Jpn. 63 : 417-424.
9. Gnanamanickam, S.S. and Mew, T.W. (1992). Biological control of blast disease of rice (*Oryza sativa* L.) with antagonistic bacteria and its mediation by a *Pseudomonas* antibiotic. Ann. Phytopathol. Soc. Jpn. 58 : 380-385.
10. Iwano, M. (1987). Biological control of blast disease through resistance of rice plant induced by incompatible strain of blast fungus. Annu. Rept. Plant Prot. North Japan 38 : 10-11 (in Japanese).
11. Iwano, M. (1987). Suppression of rice blast infection by incompatible strain of *Pyricularia oryzae* Cav. Bull. Tohoku Natl. Agric. Exp. Stn. 75 : 27-39 (in Japanese with English summary).
12. Iyozumi, H., Komagata, T., Hirayae, K., Tsuchiya, K., Hibi, T. and Akutsu, K. (1996). Biological control of cyclamen gray mould (*Botrytis cinerea*) by *Serratia marcescens* B2. Ann. Phytopathol. Soc. Jpn. 62 : 559-565.
13. Jarvis, W.R. and Slingsby, K. (1977). The control of powdery mildew of greenhouse cucumber by water sprays and *Ampelomyces quisqualis*. Plant Dis. Rep. 61 : 728-730.
14. Klecan, A.L., Hippe, S. and Somerville, S.C. (1990). Reduced growth of *Erysiphe graminis* f. sp. *hordei* induced by *Tilletiopsis pallescens*. Phytopathology 80 : 325-331.
15. Mandeel, Q. and Baker, R. (1991). Mechanisms involved in biological control of Fusarium wilt of cucumber with strains of nonpathogenic *Fusarium oxysporum*. Phytopathology 81 : 462-469.
16. Mari, M., Guizzardi, M., Brunelli, M. and Folchi, A. (1996). Postharvest biological control of grey mould (*Botrytis cinerea* Pers. : Fr.) on fresh-market tomatoes with *Bacillus amyloliquefaciens*. Crop Prot. 15 : 699-705.
17. Namai, T., Fukushima, R., Ishibashi, Y., Ohba, A. and Togashi, J. (1997). Variation in pathogenicity of incompatible races of rice blast fungus, *Pyricularia oryzae* Cavara on panicles of newly developed rice cvs. Haenuki and Domannaka. Ann. Phytopathol. Soc. Jpn. 63 : 37-43 (in Japanese with English summary).
18. Ohata, K. and Kozaka, T. (1967). Interaction between two races of *Piricularia oryzae* in lesion-formation in rice plants and accumulation of fluorescent compounds associated with infection. Bull. Natl. Inst. Agric. Sci., Ser. C. Plant Pathology and Entomology. 21 : 111-132 (in Japanese with English summary).
19. Tsukamoto, H., Gohbara, M., Tsuda, M. and Fujimori, T. (1997). Evaluation of fungal pathogens as biological control agents for the paddy weed, *Echinochloa* species by drop inoculation. Ann. Phytopathol. Soc. Jpn. 63 : 366-372.
20. Tsukamoto, H., Tsuda, M. Gohbara, M. and Fujimori, T. (1998). Effect of water management on mycoherbicidal activity of *Exserohilum monoceras* against *Echinochloa oryzicola*. Ann. Phytopathol. Soc. Jpn. 64 : 526-531.
21. Urquhart, E.J., Menzies, J.G. and Punja, Z.K. (1994). Growth and biological control activity of *Tilletiopsis* species against powdery mildew (*Sphaerotheca fuliginea*) on greenhouse cucumber. Phytopathology 84 : 341-351.
22. Yamada, M., Kiyosawa, S., Yamaguchi, T., Hirano, T. Kobayashi, T., Kushibuchi, K. and Watanabe, S. (1976). Proposal of a new method for differentiating races of *Pyricularia oryzae* Cavara in Japan. Ann. Phytopathol. Soc. Jpn. 42 : 216-219.
23. Yamaguchi, K., Kida, M., Arita, M. and Takahashi, M. (1992). Induction of systemic resistance by *Fusarium oxysporum* MT0062 in Solanaceous crops. Ann. Phytopathol. Soc. Jpn. 58 : 16-22.

和 文 摘 要

塚本浩史・堤　史樹・小野寺和英・山田昌雄・藤森　嶺：ヒエ（*Echinochloa*）属病原菌の *Exserohilum monoceras* によるイネ葉いもちの生物学的防除

ヒエ属植物の病原菌である *E. monoceras* によるイネの葉いもちの抑制について，温室内で調べた。*E. monoceras* の分生胞子懸濁液（10^6 胞子/ml）の前接種によって，イネの品種にかかわらず，いもち病斑数が75%以上減少した。また，いもち病菌の接種の7日前までの *E. monoceras* の接種によって，いもち病斑形成は抑制された。さらに，圃場試験において，その効果について調べた。*E. monoceras* 胞子懸濁液の1回の処理によって，処理後2から6週まで85%以上いもち病斑形成が抑制された。*E. monoceras* 処理区において，非処理葉上のいもち病も抑制された。温室内試験で *E. monoceras* は全身的宿主抵抗性を誘導しなかったので，その結果は *E. monoceras* 処理による初期のいもち病の進展抑制が上位葉への感染の機会を減らしたことを示唆している。1週間ごとに2回，3回および4回の処理をしても，同様の結果となった。*E. monoceras* に罹病したタイヌビエ（*E. oryzicola*）をイネ株条間に移植することによっても，いもち病は抑制された。この結果は，罹病タイヌビエ上の病斑に形成された分生胞子がイネに付着し，いもち病が抑制されたことを示唆している。さらに，慣行薬剤処理を対照として，イネの生育および収量に対する *E. monoceras* 処理の影響について，圃場で調べた。1回あるいは2回処理では，稈長，穂長，穂数，乾物重および収量に影響はなかった。しかしながら，3回処理では稈長が減少し，4回処理では稈長，乾物重および収量が減少した。以上の結果は，2回以内の処理であれば，*E. monoceras* はイネに影響を与えることなく，イネ葉いもちを防除できる生物防除剤の素材となりうることを示している。