Mycoscience 36: 439–445, 1995

Pink root rot, a revised name of brown root rot of gentian, and the causal fungi, *Pyrenochaeta gentianicola* sp. nov. and *P. terrestris* in Japan*

Tsuneo Watanabe [1] and Syoji Imamura [2]

[1] Forestry and Forest Products Research Institute, P.O. Box 16, Tsukuba S.C., Iabaraki 305 Japan
[2] Nagano Prefectural Nansin Experiment Station, Shimoichida 3,333, Takamori, Shimoina, Nagano 399-31, Japan

Accepted for publication 1 November 1995

Cultivated gentian (*Gentiana scabra* var. *buergeri*) has been seriously damaged by pink root rot since the 1970s. Diseased plants finally collapse after wilting and stunting. More than 40 fungal genera were found to be associated with roots of mature and immature diseased plants or seeds. Among these fungi, *Pyrenochaeta gentianicola* sp. nov. and *P. terrestris* were almost always associated with the diseased plants. Their morphologies and temperature responses were compared, and their pathogenicity was also demonstrated by artificial inoculation tests.

Key Words——associated fungus flora; gentian; pathogenicity; pink root rot; *Pyrenochaeta gentianicola*; *Pyrenochaeta terrestris*.

Gentian (*Gentiana scabra* Bunge var. *buergeri* Maxim.) is a perennial herb that has been commercially cultured for cut flowers since the 1950s and has expanded recently to occupy more than 600 ha. In the 1970s, more than 80% of the total cultivated area of gentian in Japan was located in Nagano Prefecture, but the area there has gradually fallen to less than 100 ha, probably due to damage by what was tentatively called "red root disease" among growers in those days.

Although the disease name "pink root" is used for the disease of *Allium cepa* L. caused by *Pyrenochaeta terrestris* (Hansen) Gorenz, Walker & Larson (Farr et al., 1989), it was not adopted for the similar disease of gentian, which was named "brown root rot" by Watanabe and Imamura in 1977. However, because "pink root" is commonly used among growers today, the name "brown root rot" will be revised to "pink root rot" (*koshoku-negusare-byo* in Japanese) in this study, in which the causal fungi are identified.

A brief report of this work was presented previously (Watanabe and Imamura, 1977).

Materials and Methods

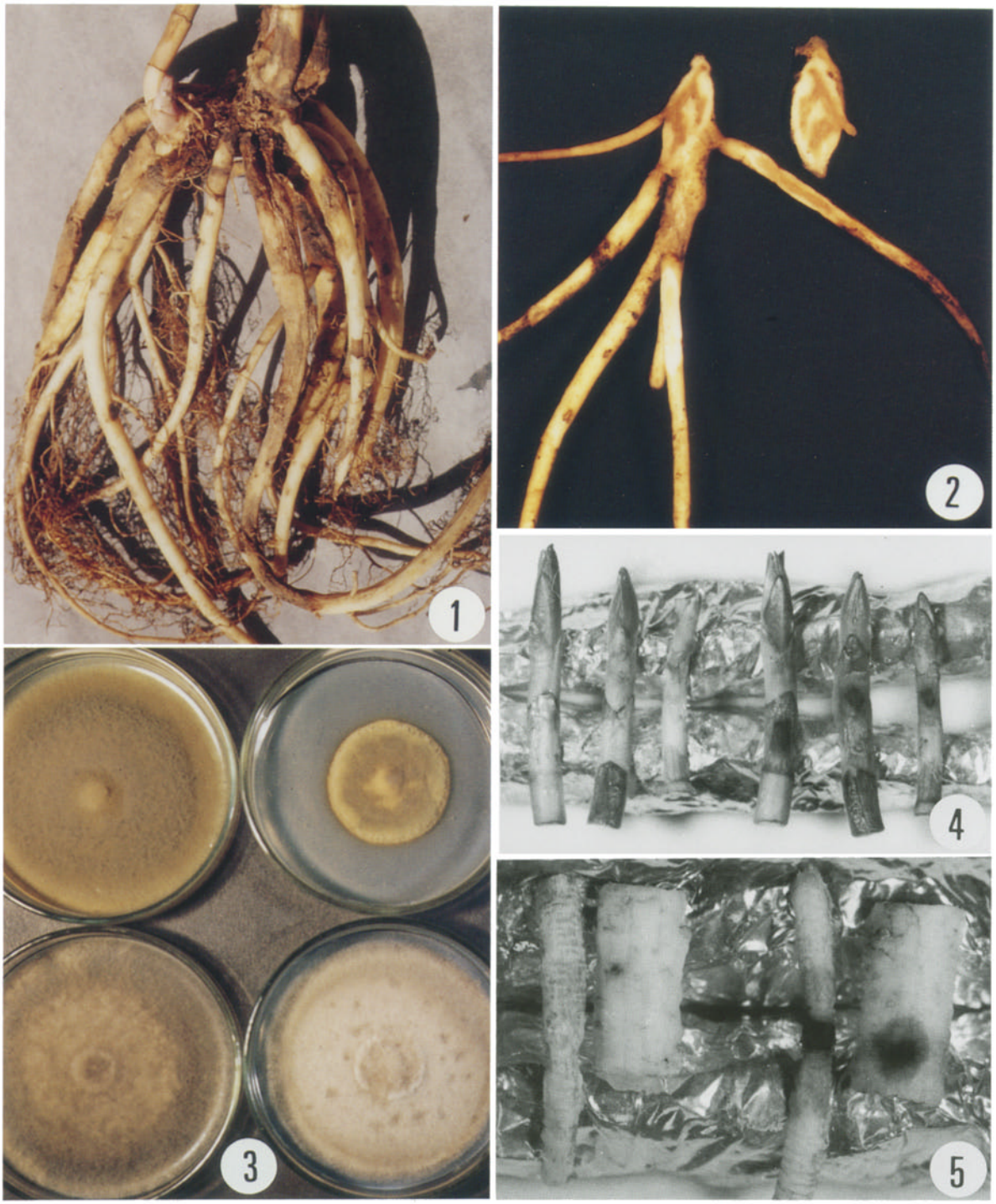
Samples and isolations Samples were collected from Kobuchizawa Cho, Yamanashi Pref., Myokokogen Machi, Niigata Pref., and Chino Shi, Nagano Pref. in June to September, 1973–1976. Fungi were obtained by single-hyphal tippings from a total of 307 root segments ($5 \times 5 \times 4$ mm) of 31 mature diseased plants (12 from Kobuchizawa, 7 from Myokokogen, and 12 from Chino) and 22 seedlings from Chino plated on water agar at 20 °C or 28 °C. A total of 12 stem segments of four mature diseased plants from Myokokogen and Chino, and 400 seeds of two strains, "White" and "Purple," stored at Nagano Prefectural Nansin Agricultural Experiment Station, were similarly treated for fungal isolation.

Fungi isolated from additional samples collected from Shimoina Gun, or Iida Shi, Nagano Pref. were also included in this study. All samples were selected at random, washed under running tap water, air-dried and plated on water agar without surface sterilization.

Temperature responses of *Pyrenochaeta* spp. Temperature responses of two *Pyrenochaeta* species at seven temperatures, 10, 15, 22, 25, 28, 30, and 37 °C, were compared by measuring the diameters of colonies on potato-dextrose agar (PDA) 5 days after inoculation (Fig. 2). Inocula consisted of a 4-mm-diam mycelial agar discs removed from the margin of 5-day-old colonies grown on PDA at 25 °C, using an aseptic cork borer. Measurements of the colony diameter represent an average of six replicates in two experiments.

Inoculation tests In preliminary studies, 12 representative fungus isolates, two *Pyrenochaeta* species, three *Fusarium oxysporum*, two *F. solani*, two *Rhizoctonia solani* and three unknowns, were inoculated. Inoculation was conducted by transplanting two-month old seedlings into artificially-infested potted soil (200 g of soil with 100 g of 10-day-old soil-rice bran culture (soil, 40 g; rice bran, 60 g; water 30 ml) in 6.2-cm-diam clay pots buried in the field (soil temperatures 20–28°C) of Nagano Prefectural Nansin Agricultural Experiment Station at Shimoina, Nagano in June to September, 1976. The ex-

*Part of this work was conducted at the National Institute of Agricultural Sciences (presently National Institute of Agro-Environmental Sciences), Tsukuba S.C., Ibaraki 305, Japan by T. Watanabe.



Figs. 1, 2. Pink root rot of gentian caused by *Pyrenochaeta* species. Note internal discoloration of tangentially-cut surface of the root (2). Fig. 3. Colonies of *Pyrenochaeta gentianicola* (upper two plates) and *P. terrestris* (lower two plates) at 25 °C (left) and 28 °C (right) 18 days after inoculation in 9-cm diam Petri dishes. Figs. 4, 5. Symptoms developed on the right three gentian shoots (4) and two root segments (5) 12 days after inoculation with *Pyrenochaeta gentianicola*, with healthy segments with sterile PDA discs (left three shoots and two root segments) as controls.

periments were conducted twice using four pots per treatment in one experiment under artificial cover with black lawn.

In further studies with *P. gentianicola* (isolate TW 76-501) and *P. terrestris* (76-502), inoculation experiments were conducted in vitro at 16, 20, and 26°C by placing inocula (4-mm-diam agar discs removed from margin of 8-day-old PDA cultures at 25°C) or sterile agar

discs on 4-7 cm visually healthy root and shoot segments (over 5 mm diam), using six segments in each test, and experiments were repeated two or three times.

Results and Discussion

Symptoms Damage occurred at various stages from immature seedlings to mature plants, including poor ratooning, stunting, wilting and collapse of the whole plant. Roots and stems of infected plants were often shrivelled, baggy in the epidermis, sometimes corky, damaged partially or entirely, with pale brown, brown to reddish brown, water-soaked sunken lesions and often discolored to yellowish brown to brown in vascular bundles. Root tips were occasionally readily broken or shredded off. Buds and shoots in soil were often similarly diseased (Figs. 1, 2).

Fungi obtained To understand the fungal community occurring in the diseased areas, a total of 441 isolates were obtained by single-hyphal tipping from a total of 307 root segments of 31 mature diseased plants and 22 seedlings. Whole data were summarized without differentiation between fungi associated with the diseased tissues and visually healthy tissues, because no clear-cut differences were noticed.

A total of 251 isolates from mature plant roots and 190 from seedling roots belonged to at least 38 genera (species name and isolate number of representative isolates are given in parentheses): *Alternaria* Nees ex Fr. (*A. alternata* (Fr.) Keissler, 73-909; 76-513), *Arthrinium* Kunze ex Fr. (detected, but not isolated=DNI), *Aspergillus* Mich. ex Fr. (*Aspergillus* spp., 76-523; -529), *Aureobasidium* Viala & Boyer (*A. bolleyi* (R. Sprague) Arx, 75-93; *Aureobasidium* sp., 75-105), *Botrytis* P. Mich. ex Pers. (*B. cinerea* Pers: Fr., 75-49; 76-568), *Candida* Berkhout (*Candida* spp., 74-359; 75-42; -54; -62), *Chalara* (Corda) Rabenh. (*Chalara* sp., 75-106), *Chloridium* Link (76-519), *Cladosporium* Link (*C. cladosporioides* (Fres.) de Vries, 75-228), *Chromelosporium* Corda (*C. fulvum* (Link) McGinty, Hennebert & Korf, 76-572; -573), *Curvularia* Boedijn (*C. affinis* Boedijn, 76-545), *Cylindrocarpon* Wollenw. (*C. destructans* (Zins.) Scholten, 75-138; 76-550), *Dendryphion* Wallr. (*Dendryphion* sp., 76-546), *Epicoccum* Link ex Fr. (*E. purpurascens* Ehrenb. ex Schlecht., 75-116; 76-512), *Fusarium* Link ex Fr. (*F. oxysporum* (Schl.) emend. Snyder & Hansen, 74-360; 75-59; -125; 76-503), (*F. roseum* (Link) Snyder & Hansen, 75-126; 76-514; -524), (*F. solani* (Mart.) App. & Wr. emend. Snyder & Hansen, 75-53; -94; -132; 76-504), *Geotrichum* Link ex Pers. (DNI), *Gliocladium* Corda (*G. virens* Miller, Giddens & Foster, 76-533; *Gliocladium* sp., 73-901), *Gonatobotrys* Corda (DNI), *Gonytrichum* Nees ex Leman (*Gonytrichum* sp., 75-340), *Humicola* Traaen (*Humicola* sp., 76-551), *Macrophoma* (Sacc.) Berl. & Vogl. (*Macrophoma* sp., 76-520), *Macrophomina* Petrak (*M. phaseolina* (Tassi) Goidanich, 75-111; 76-510), *Monacrosporium* Oudem. (*Monacrosporium* sp., 75-111), *Monilia* Pers. ex Fr. (*M. pruinosa* Cooke & Masse, 75-43; -44; 76-521), *Mortierella* Coemans (*Mortierella* spp., 73-905; 76-543), *Mucor* Micheli ex Fr. (*Mucor* spp., 75-136; -143; 76-135), *Nigrospora* Zimmerm. (*N. oryzae* (Berkeley & Broome) Petch, 76-541), *Paecilomyces* Bain. (DNI), *Penicillium* Link (*Penicillium* spp., 76-518; -530; -540; -548; -585), *Periconia* Tode ex Schw. (*P. macrospinosa* Lefebvre & Johnson, 76-509; -547), *Phoma* Sacc. (*Phoma* spp. 76-536; -570), *Pyrenochaeta* de Not. (*Pyrenochaeta* spp., described later), *Pythium* Pringsheim (*P. sylvaticum* Campbell & Hendrix, 76-507), *Rhizoctonia* DC. & Fr. (*R. fragariae* Hussian & W. E. McKeen, 73-912; *Rhizoctonia* spp., 75-114; 76-555), *Septonema* Corda (*S. chaetospira* (Grove) Hughes, 76-556), *Tetracladium* de Wild. (*T. setigerum*, 75-137 (=ATCC 34349)), *Torula* Pers. & Fr. (*Tolula* spp., 73-913; 75-268; 76-526), *Trichoderma* Pers. ex Fr. (*T. hamatum* (Bonorden) Bain., 75-92; 76-532, *Trichoderma* sp., 76-511), *Volutella* Tode ex Fr. (*Volutella* sp., 75-96; -136; -142), and unknown fungi (76-45; -520; -576).

The four genera most frequently isolated from the respective locations were tabulated together with the number of isolates (Table 1). *Fusarium* and *Pyrenochaeta* are the most dominant genera, being isolated from every sample tested. *Pyrenochaeta* species were often readily observed on the diseased roots under the dissecting microscope at 30×.

From 12 stem segments, nine genera were obtained: *Candida* (75-147), *Dactylaria* Sacc. (*Dactylaria* sp., 75-144), *Fusarium*, *Gliocladium*, *Mortierella* (75-117), *Monacrosporium* (75-118), *Monilia*, *Pyrenochaeta*, *Trichoderma*, and unknown fungi.

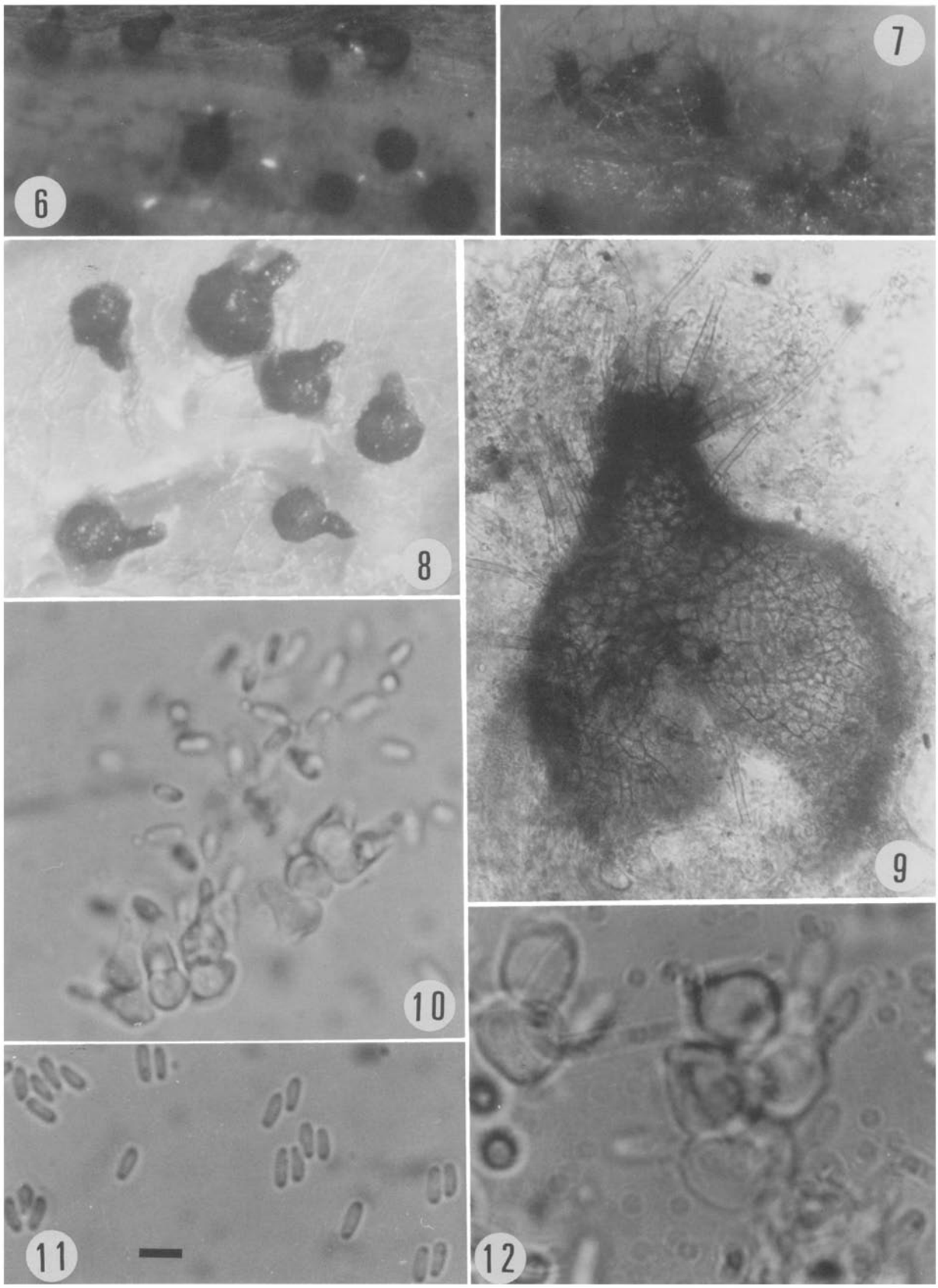
From 400 seeds, 10 genera were identified: *Alternaria*, *Arthrinium* (75-157), *Bispora Corda* (*B. betulina* (Corda) S. J. Hughes, 75-155), *Cladosporium*, *Fusarium*, *Gliocladium* (75-149), *Mucor* (75-156), *Penicillium*, *Phoma* (75-227) and *Trichoderma*.

Several of the isolated fungi, including *Tetracladium setigerum* and *Bispora betulina*, were described and illustrated elsewhere (Watanabe, 1993, 1994). Most of the isolates obtained are deposited in the Gene Bank, National Institute of Biological Resources, Ministry of Agriculture, Forestry, and Fisheries (MAFF) at Tsukuba.

Distribution of *Pyrenochaeta* spp. During isolation processes, setose pycnidia and chlamydospore-like structures, supposedly immature pycnidia, were occasionally observed on the root surface of the diseased plants, especially in the samples placed under wet conditions.

Table 1. The most frequently isolated fungus genera from gentian roots together with the number of isolates from Kobuchizawa (Yamanashi Pref.), Myokokogen (Niigata Pref.) and Chino (Nagano Pref.).

Location	Number of isolates	Fungus genera (no. of isolates)
Kobuchizawa	95	*Trichoderma* (36), *Fusarium* (21), *Monilia* (13), *Pyrenochaeta* (8)
Myokokogen	59	*Fusarium* (38), *Pyrenochaeta* (9), *Candida* (3), *Gliocladium* (3)
Chino	287	*Fusarium* (75), *Pyrenochaeta* (63), *Trichoderma* (44), *Gliocladium* (12)


6
7
8
9
10
11
12

Two types of fungi with setose pycnidia were consistently isolated from diseased roots and shoots. For example, all but 1 of 17 three-month-old seedlings arbitrarily selected from a randomly selected nursery at Iida, Nagano Pref. in 1976, were infected with *Pyrenochaeta* spp. Nine seedlings yielded both *Pyrenochaeta* species, and the remaining seven yielded one or the other of the these species.

Morphology and identification of *Pyrenochaeta* species

Pyrenochaeta gentianicola T. Watanabe, sp. nov.
Figs. 3 (upper two plates), 6-12

Coloniae in agaro decocto tuberorum post 5 dies ad 25°C 31-34 (32.6) mm diam attingentes, flavovirentes, reverso phaeoflavovirenti. Pycnidia dispersa, solitaria vel aggregata, globosa vel subglobosa, atrobrunnea vel nigra, peridiis pseudoparenchymaticis, papillata vel ostiolata, (82-) 107-333.5 μm crassa, collo longo, 49.5-210×39.5-75 μm. Setae brunneae, simplices raro ramosae, plerumque 3-5-septatae, attenuatae ad apicem, (12.5-) 35-200 μm longae, 3-7.5 μm latae ad basim, 2-3 μm latae ad apicem. Cellulae conidiogenae hyalinae, simplices, ampulliformes vel lageniformes, phialidicae, enteroblasticae, collumella parva inconspicua, aseptatae, raro 1-septatae, 4.7-9.5×2.8-4.8 μm ad basim, 0.9-5.7×0.7-1.1 μm ad apicem. Conidia (phialoconidia) hyalina, unicellularia, ellipsoidea, eguttulata vel 2-guttulata, 2.8-5(-5.2)×0.5-1.5(-2.5) μm.

Holotypus: TW 76-501 (FFPRI).

Paratypus TW 75-40; -97; -102; -108; -229; -231; -232; 76-589 (MAFF).

Colonies yellowish green superficially, smooth marginally, aerial, reverse dark yellow-green. Pycnidia solitary or rarely aggregated, black or dark brown, superficial, rarely embedded, globose or subglobose, composed of pseudoparenchymatous tissue, well-necked or ostiolate with setae surrounded, (82-)107-333.5 μm in diam excluding necks, necks 49.5-210×39.5-75 μm. Setae brown, mostly 3-5-septate, tapering from base towards apex, occasionally apically hyaline to subhyaline, branched occasionally, (12.5-)35-200 μm long, 3-7.5 μm wide at base, 2-3 μm wide at apex. Conidiophores ampulliform with abruptly sharpened or narrowed tips from the median or lageniform, occasionally 1-septate, 4.7-9.5×2.8-4.8 μm in basal portion, 0.9-5.7×0.7-1.1 μm at apical portion. Conidia hyaline, elliptical to rather cylindrical, 1-celled, eguttulate or biguttulate, 2.8-5(-5.2)×0.5-1.5(-2.5) μm. The pycnidial primordia resembling chlamydospores numerous, single or catenulate, granular inside, usually embedded, 15-26.3 μm in diam; sclerotium-like structures 27.5-95 μm in diam. Similar structures were described previously (Hansen 1929; Kreutzer, 1941), and also found in *P. terrestris* in this study.

Hab.: On roots of gentian (*Gentiana scabra* Bunge var. *buergeri* Maxim.), Chino and Iida, Nagano Pref., Kobuchizawa, Yamanashii Pref., and Myokokogen, Niigata Pref., Japan.

Materials: Cultures from roots of gentian, Chino, Nagano Pref., Japan, 19 October 1976, T. Watanabe TW 76-501 (FFPRI; Holotype); 14 June 1975, TW 75-108; -229 (FFPRI; Paratype); Kobuchizawa, Yamanashi Pref., 14 June 1975, T. Watanabe TW 75-40; -97; -102 (FFPRI; Paratype); Myokokogen, Niigata Pref., 14 June 1975, T. Watanabe TW 75-231; -232; Iida, Nagano Pref., 5 October 1976, T. Watanabe TW 76-589 (FFPRI; Paratype) deposited in the Herbarium, Forestry and Forest Products Research Institute (FFPRI) and the National Institute of Biological Resources, Ministry of Agriculture, Forestry and Fisheries (MAFF) at Tsukuba S.C., Ibaraki, Japan.

Only 11 species were accepted by Schneider (1976) among some 120 *Pyrenochaeta* species described, based on setose pycnidia and branching conidiophores, with the type species *P. nobilis* De Notaris redescribed. Sutton (1980) agreed with Schneider (1976), also noting the need for a new generic name for the fungus species with setose pycnidia. Recently, *P. ligni-putridi* was named by Sieber (1995), following Schneider (1976), although it formed 1-septate conidia.

However, *P. globosa* T. Watanabe with setose pycnidia and simple conidiophores was included in *Pyrenochaeta* by Watanabe (1992), because he believed that the setose character of the pycnidia should be emphasized over the character of simple or branched conidiophores at the generic level if the conidiogenous cells are phialidic. Therefore, this fungus was described as a new species of *Pyrenochaeta*, following Watanabe (1992), because no species described resembles this fungus morphologically.

Pyrenochaeta terrestris (Hansen) Gorenz, Walker & Larson, Phytopathology 38: 831-840. 1948.
Figs. 3 (lower two plates), 13-16

Colonies gray superficially, irregular marginally, reverse dark brown to black. Pycnidia solitary or aggregated, globose or subglobose, dark brown to black, 123.5-296.5 μm in diam, ostiolate, usually non-necked, surrounded with setae, ostioles 15-20 μm in diam. Setae brown, usually 3-septate, 50-142.5 μm long, 2-4.5 μm wide at base, 0.5-2 μm wide at apex. Conidiophores obpyriform, 4.6-6.6×1.3-2.8 μm. Conidia hyaline, elliptical, with 2-4 oil globules, (4.8-)5-5.5×2.3-2.8(-3) μm. Pycnidial primordia resembling chlamydospores 9-15 μm in diam or sclerotium-like structures 25-85 μm in diam.

Hab.: On roots of gentian (*Gentiana scabra* Bunge

Figs. 6-12. *Pyrenochaeta gentianicola*.
6, 7. Pycnidia formed on gentian straw in water agar used as natural medium. Note several aerially-developed necks and embedded pycnidia on the tissue surface (7). 8. Pycnidia formed in agar medium. 9. Crushed pycnidium. Note a neck and the setae around. 10. Conidiophores and conidia. 11. Conidia. 12. Close-up of conidiophores. Scale bar in Fig. 11: Figs. 6, 8=150 μm; Fig. 7=100 μm; Fig. 9=15 μm; Figs. 10, 11=5 μm; Fig. 12=2.5 μm.

var. *buergeri* Maxim.), Shimoina, Chino, and Iida, Nagano Pref., Kobuchizawa, Yamanashi Pref., and Myokokogen, Niigata Pref., Japan.

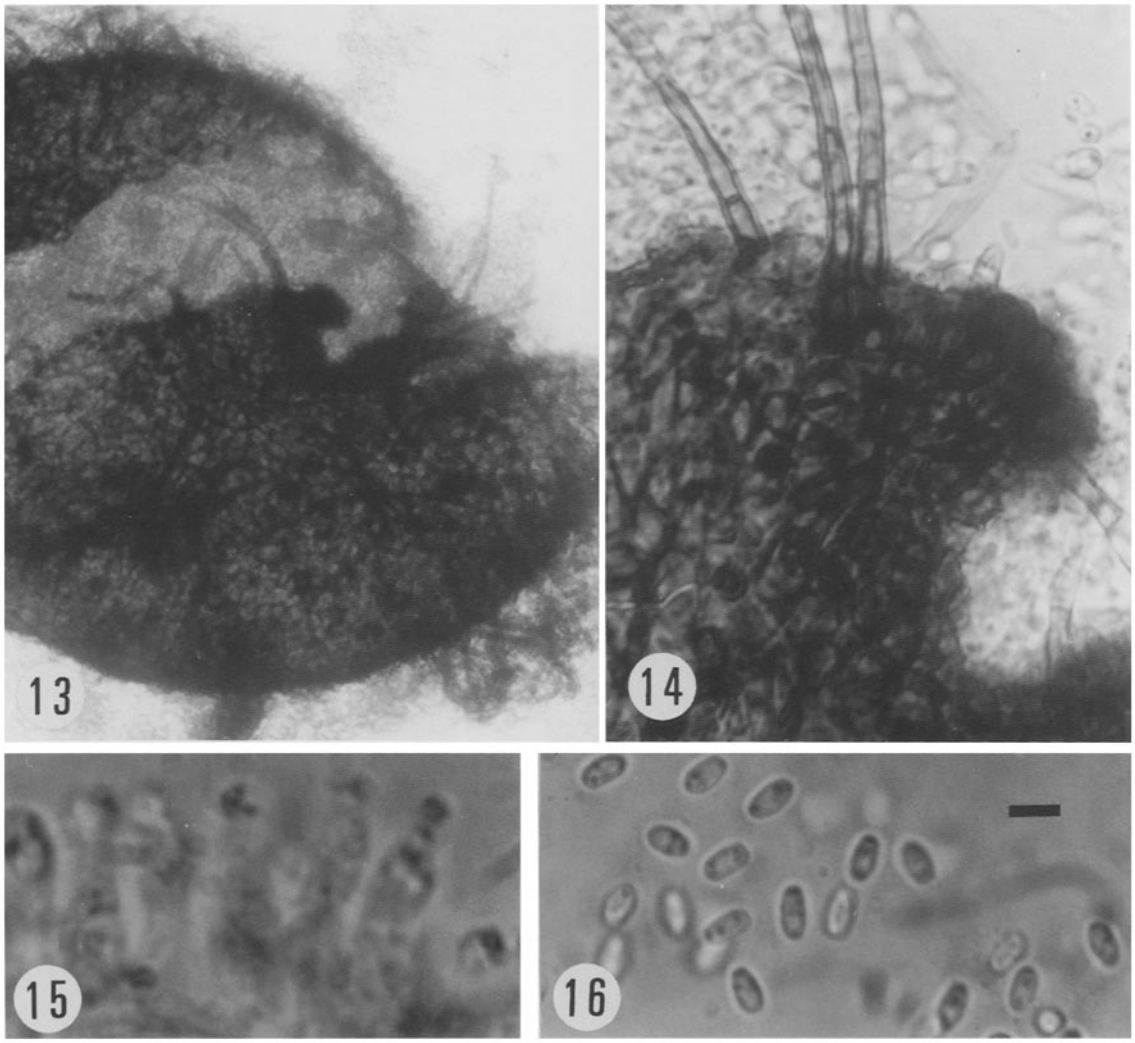
Materials: Cultures from roots of gentian, Shimoina, Nagano Pref., Japan, 13 November 1973, T. Watanabe TW 73-910; Kobuchizawa, Yamanashi Pref., 14 June 1975, T. Watanabe TW 75-38; -39; Chino, Nagano Pref., 14 June 1975, 75-54; -107; -113; 19 October, 1976, TW 76-502; -535; -537; Iida, Nagano Pref., 19 October 1976, T. Watanabe TW 76-587 deposited in FFPRI and MAFF.

Phoma terrestris Hansen (1929), the causal fungus of the pink root disease of onions, was transferred to *Pyrenochaeta* by Gorenz et al. in 1948 because of the setose character of the pycnidia, but its validity is controversial because the morphology of conidiophores is not described. It is identified as *Pyrenochaeta terrestris* on the basis of overall morphological similarity. It is slightly different from the original description in the number of conidial guttulation and the conidial width, but the presence of numerous variations of the species has been noted by previous workers (Gorenz et al., 1948; Hansen, 1938). Pycnidial primordia (Hansen, 1929; Kreutzer, 1941) resembling chlamydospores or sclerotium-like structures were also found in this fungus.

Temperature responses of *Pyrenochaeta* species Both *Pyrenochaeta* species grew well at 10-30°C with the optimum temperature of 25°C, but showed no growth at 37°C. *Pyrenochaeta gentianicola* grew better than *P. terrestris* below 25°C, but poorer above 28°C (Figs. 3, 17).

These two *Pyrenochaeta* species were readily differentiated from each other by colony color, shape of pycnidia, conidiophores, and conidia and temperature responses.

In *P. gentianicola*, which was previously described as *Pyrenochaeta* sp. and illustrated by T. Watanabe in 1993 and 1994, PDA colonies are yellowish green superficially, dark yellow-green in reverse, and pycnidia are always necked. Conidiophores are ampulliform or lageniform,



Figs. 13–16. *Pyrenochaeta terrestris*.
13. Crushed pycnidium. 14. Close-up of Fig. 13. Scale bar in Fig. 16: Fig. 13=20 μm; Figs. 14, 16=5 μm; Fig. 15=2 μm.

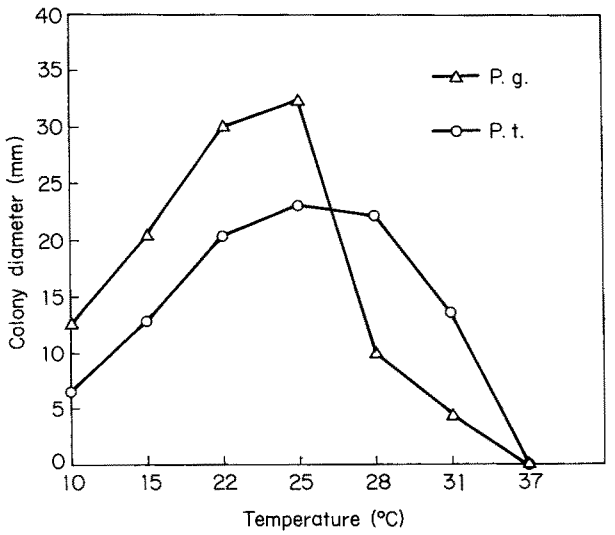


Fig. 17. Colony diameter (mm) of *Pyrenochaeta gentianicola* (=P.g.) and *P. terrestris* (=P.t.) 5 days after inoculation on PDA dishes at seven different temperatures.

and conidia are elliptical to rather cylindrical, whereas in *P. terrestris*, colonies are gray in surface, dark brown to black in reverse, and pycnidia are mostly unnecked but ostiolate. Conidiophores are obclavate, cylindrical, tapering towards apex, and conidia are elliptical.

These two *Pyrenochaeta* species also differ from *Phoma gentianea* J. Kuehn, the only pycnidial fungus species from *Campunula* (Farr et al., 1989; Saccardo, 1884), because conidia of the latter are ovate to oblong, and 7-8 × 1.8-2.2 μm, whereas those of *P. gentianicola* and *P. terrestris* are elliptical to cylindrical, and their respective dimensions differ: 2.8-5(-5.2) × 0.5-1.5(-2) μm, and (4.8-)5-5.5 × 2.3-2.8(-3) μm.

Inoculation tests Among the 12 representative fungus isolates tested in preliminary studies, *Pyrenochaeta* spp. and *Fusarium oxysporum* were pathogenic to the seedlings transplanted in the artificially-infested potted soil.

The *Pyrenochaeta* spp. were strongly pathogenic, causing stunting of the whole seedlings. The diseased seedlings had poor root systems and 25% of tap roots and 8.3% of subsidiary roots were discolored yellowish brown and shrunken.

Fusarium oxysporum was weakly pathogenic, causing partial discoloration of 13% of tap roots. No disease occurred in the soil infested with other fungi and uninfested soil tested as control.

On the yellowish brown-discolored tissue of the diseased roots infected with *P. gentianicola* kept moist, aerial necks and embedded pycnidia were readily observed (Fig. 7).

From all diseased plants inoculated, the respective inoculated fungi were recoverable.

In inoculation experiments conducted in vitro to further confirm the pathogenicity of the *Pyrenochaeta* isolates, water-soaked brown lesions readily developed around inoculum on 4-7 cm root segments inoculated at 16, 20 and 26°C (Fig. 5, Table 2). Similar results were obtained in the inoculation of shoot segments (data not shown) (Fig. 4). Pathogenicity of *P. gentianicola* was also confirmed in Kumamoto Pref. in 1978 (Nakayama, T., personal communication).

Pyrenochaeta gentianicola appeared to be more pathogenic than *P. terrestris*, as demonstrated in vitro (Table 2) and in field inoculation studies. Therefore, both fungi frequently associated with the diseased plants were concluded to be the main cause of the pink root rot of gentian.

Table 2. Pathogenicity[a] of *Pyrenochaeta gentianicola* (isolate TW 76-501) and *P. terrestris* (76-502) toward gentian root segments 12 days after inoculation at 16, 20, and 26°C.

	Diseased segments (%)			Lesion length (mm)		
	16°C	20°C	26°C	16°C	20°C	26°C
Control	0A[b]	2.8A	16.7A	0A	0A	0.1A
P. gentianicola	70.9B	80.6B	54.2B	6.6B	6.3B	4.9AB
P. terrestris	4.2A	38.9A	45.9AB	0A	2.3A	7.8B

[a]Percentage of diseased root segments in a total of 18 root segments inoculated in each treatment and average lesion length (mm) per segment 12 days after inoculation in three separate experiments.

[b]Values with the same letter in the same column do not differ significantly ($P=0.05$) according to the least significant difference test.

Literature cited

Farr, D. F., Bills, G. F., Chamuris, G. P. and Rossman, A. Y. 1989. "Fungi on plants and plant products in the United States," APS Press, St. Paul. 1252 p.

Hansen, H. N. 1929. Etiology of the pink-root disease of onions. Phytopathology **19**: 691-704.

Hansen, H. N. 1938. The dual phenomenon in imperfect fungi. Mycologia **30**: 442-455.

Kreutzer, W. A. 1941. Host-parasite relationships in pink root rot of *Allium cepa*. II. The action of *Phoma terrestris* on *Allium cepa* and other hosts. Phytopathology **31**: 907-915.

Saccardo, P. A. 1884. "Sylloge fungorum," Vol. 3, p.120.

Schneider, R. 1976. Taxonomie der Pyknidienpilzgattung *Pyrenochaeta*. Ber. Deutsch. Bot. Ges. **89**: 504-514.

Sieber, T. N. 1995. *Pyrenochaeta ligni-putridi* sp. nov., a new coelomycete associated with butt rot of *Picea abies* in Switzerland. Mycol. Res. **99**: 274-276.

Sutton, B. C. 1980. "The Coelomycetes," Commonwealth Mycol. Inst., Kew. 696 p.

Watanabe, T. 1992. A new species of *Pyrenochaeta* from Japanese black pine seeds. Trans. Mycol. Soc. Japan **33**: 21-24.

Watanabe, T. 1993. "Photomicrographs and illustrations of soil fungi," p. 318. Soft Science Publications, Tokyo. (In Japanese.)

Watanabe, T. 1994. "Pictorial atlas of soil and seed fungi," p. 335-336. Lewis Publishers, Boca Raton.

Watanabe, T. and Imamura S. 1977. Brown root rot (new disease) of gentian and the causal fungi, *Pyrenochaeta* species. Ann. Phytopathol. Soc. Japan **43**: 343 (Abstr. in Japanese.)