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Occurrence of Phytophthora Root Rot on Kiwifruit in Korea

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A severe root rot of kiwifruit caused by a species of *Phytophthora* occurred in 1- to 5-year-old vines at the south coast region of Korea in 1997. Infected vines exhibited leaf chlorosis, scorch and defoliation, root and stem rot, and eventual death. The disease was relatively severe in poorly drained lowlands, of which 19 out of 23 fields were damaged by the disease. Meanwhile, only one among 58 upland fields was infected by the disease. Incidence of infected vines reached over 80% in heavily damaged fields and a species of *Phytophthora* was isolated from inner tissues of roots, stems, and rhizosphere soils of the plants. The causal pathogen was identified as *P. drechsleri* based on its mycological characteristics. Pathogenicity of the fungus was confirmed by artificial inoculation to seedlings of kiwifruit 'Hayward'. The pathogen was re-isolated from the inoculated plants showing symptoms similar to those observed in the fields. Root rot of kiwifruit caused by *P. drechsleri* has not been reported previously in Korea.

Keywords : kiwifruit, *Phytophthora drechsleri*, root rot.

After kiwifruit (*Actinidia deliciosa*) was introduced commercially in Korea in 1978, it is now grown in over 1,270 ha in the south coast regions of Korea. Recently, young kiwifruit plants have been severely damaged by root rot in some poorly drained fields with dieback symptoms. The dieback of plants had been previously considered winter injury or wet feet from farmers. However, considering the epidemic nature of the damage, it was suspected that some pathogens may be related to the disease. In particular, *Phytophthora* spp. was believed to be the possible cause because the fungus has been reported as the major pathogen causing similar diseases in kiwifruit in New Zealand, California, Chile, and France (Stewart and McCarrisan, 1991; Conn et al., 1991; Latorre et al., 1991; Baudry et al., 1991).

During a survey on kiwifriut diseases in 1997, a species of *Phytophthora* was consistently isolated from the diseased plants showing destructive root rot. The disease spread widely to many kiwifruit-growing areas in the south coast, and appeared to be a threat to kiwi cultivation in Korea. In this paper, *Phytophthora* root rot of kiwifruit is firstly reported in the country, along with identification and pathogenicity test of the causal pathogen.

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Materials and Methods

Disease survey. A survey on *Phytophthora* diseases of kiwifruit was conducted in Koheung, Bosung, Muan, Haeanam, Sunchon, Jindo, Sachon, and Namhae in the south coast regions of Korea in 1997. A total of 58 upland and 23 lowland fields were investigated separately in the areas. Declining kiwi vines associated with typical root rot were counted as infected by the disease.

Isolation of the causal pathogen. Direct isolation of the causal fungus was carried out in kiwifruit orchards using a water agar and a semi-selective medium for *Phytophthora* (Jee et al., 1997a). Small pieces (2-3 mm^3) of the infected inner tissues of the secondary roots or stems were cut by a scalpel after removal of the epidermis and bark. The pieces were placed on the media without surface disinfection and incubated for 2-3 days at 25°C. Growing mycelial tips from the pieces were cut and transferred into 10% clarified V8 agar for further studies. The semi-selective medium used in this study consisted of corn meal agar (CMA; Difco, 17 g/L) supplemented with 100 ppm ampicillin, 50 ppm nystatin, and 10 ppm pentachloronitrobenzene (PCNB). The 10% clarified V8 juice (Campbell, USA) was centrifuged at 7,000 rpm for 20 min prior to use. Deionized water and 18 g of agar were added to 100 ml of the supernatant of the juice to make 1000 ml of 10% clarified V8 agar.

Identification. To examine sporangial production of single isolate on agar, all isolates were cultured on 10% clarified V8 agar for 7-14 days under light and in the dark at 20°C (Jee et al., 1997a). Seven-day-old cultures grown on 10% clarified V8 agar were cut into small pieces (ca. 10 × 10 mm) to investigate the sporangial characteristics. The agar blocks were immersed in sterilized water in a petri plate and incubated at 25°C under light for 24-48 hours. Sporangia formed in water were agitated in a Vortex mixer to examine their caducity. Sporangia formed on the agar block in water were observed under a light microscope either directly or on a glass slide. At least 20 sporangia for each isolate were examined.

To induce sexual reproduction of heterothallic isolates, both A1

and A2 mating types of *P. capcisi* 8710 (A1) and 8814 (A2), and *P. cryptogea* 331 (A1) and 36 (A2) were used. Oospore formation was done as described by Jee et al. (1997b).

Pathogenicity test. Two-year-old kiwifruit seedlings (cv. Hayward) were grown in sterilized sandy loam soil. Plants were pulled up and washed under running tap water. A small agar disk made by a cork borer (5 mm in diameter) from each of the 7-day-old cultures of PG 9701, PG 9702, and PG 9703 grown on 10% clarified V8 agar was attached to the primary root of kiwifruit after being scarred by cutting. Inoculated plants were transferred to pots (15 cm in diameter) containing the same soil. Three plants were inoculated per isolate, and the same number of uninoculated plants was used as control checks. The pots with inoculated and uninoculated plants were separately submerged in water 1-2 cm deep from the bottom for 24 hr, and then placed in a greenhouse for 14 days at 24-30°C. Degree of pathogenicity to the kiwi plants was graded as follow: severe=all leaves defoliated and root rot; moderate=one to three leaves defoliated and root rot; weak = only root rot.

Results

Symptoms. Diseased kiwifruits generally showed dieback symptoms with decline, leaf chlorosis and scorch, defoliation, and eventual death (Fig. 1-A). Signs of the disease such as fungal mycelium were consistently observed on the rotten roots. The symptoms were sometimes confused with stem canker by *Pseudomonas syringae* pv. *actinidae*. However, stem canker did not show any sign of root rot (Ko et al., 2000). Secondary xylem tissues decayed with reddish brown or brown discoloration. Furthermore, margins of lesions were clearly distinguished from healthy tissues when plants were heavily infected (Fig. 1-B).

Incidence of the disease. Root rot of kiwifruit was observed in 20 out of 81 fields in Koheung, Bosung, Muan, and Namhae among eight locations surveyed. The disease mainly occurred in lowland fields, except in one upland field in Koheung. There was no disease occurrence in upland fields in Haenam, Sunchon, Jindo, and Sachon. Incidence of the root rot reached over 80% in a few fields in Koheung, while it ranged from 1% to 30% in most fields at Bosung and Muan. In Namhae root rot incidence was about 10% (Table 1).

Identification. Based on morphological characteristics of asexual and sexual reproduction structures (Table 2), all isolates of *Phytophthora* isolated from kiwifruit were identified as *P. drecshleri* Tucker. All isolates grew well on 10% V8 agar and potato dextrose agar (PDA). The fungus produced fluffy aerial mycelia on 10% V8 agar and slightly rosaceous colony pattern on PDA (Fig. 2-A). The isolates grew between 5 and 35°C and maximally at 28°C. Non-papillate sporangia formed in solitude only in water, obpyriform or ovoid, internally and externally proliferated, persistent on long and slender stalks (Fig. 2-B, D, E), and sized 44-76 × 24-36 μm (av. 63.0 × 32.0 μm). The fungus was heterothallic since oospores were formed only when paired with either A1 or A2 mating type standard. Two isolates were A1 type and five isolates were A2 type. Antheridia were all amphigynous. Sizes of oogonia and oospores were measured as 24-40 μm (av. 32.0 μm) and 20-32 μm (av. 28.0 μm), respectively.

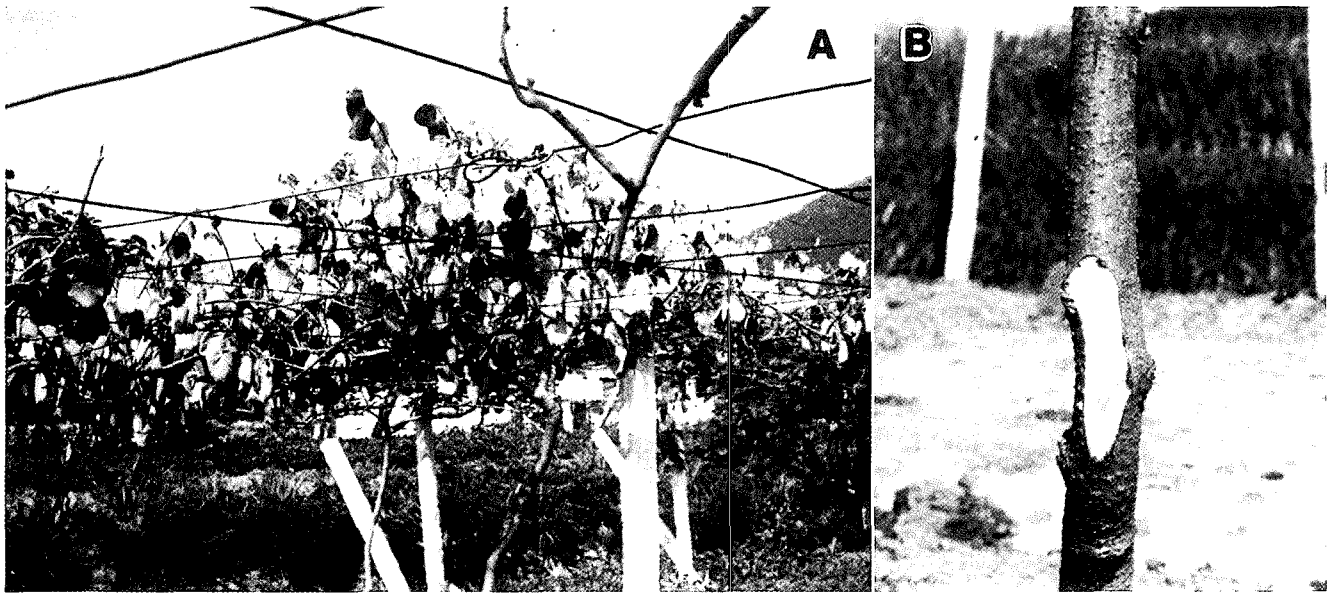

Fig. 1. Symptoms of Phytophthora root rot of kiwifruit caused by *Phytophthora drechsleri*. **A**: An infected plant showing decline. **B**: Discolorated inner phloem tissues of the infected plant.

Table 1. Incidence of *Phytophthora* root rot of kiwifruit in major cultivation areas of Korea

Surveyed area	No. of fields				Disease incidence (%)	
	Lowland		Upland			
	Surveyed	Infected	Surveyed	Infected	Lowland	Upland
Koheung	12	10	10	1	5-90	<1
Bosung	7	5	8	0	1-20	0
Muan	2	2	9	0	1-30	0
Haenam	0	0	5	0	0	0
Sunchon	0	0	4	0	0	0
Jindo	0	0	9	0	0	0
Sachon	0	0	6	0	0	0
Namhae	2	2	7	0	1-10	0
Total	23	19	58	1	0-90	0-1

Table 2. Characteristics of asexual and sexual reproduction structures of *Phytophthora* isolates from kiwifruit in comparison with *P. drechsleri*

Characteristics examined		Present isolates	*P. drechsleri* [a]
Sporangium	Formation	In water or rare on agar Inter or external Mostly single	Only in water Inter or external Single, lax sympodium
	Papillium	None	None
	Shape	Obpyrifom, ellipsoid	Broadly obpyriform, ovoid, ellipisoid
	Base	Tapered	Tapered
	Caducity	None	None
	Size (μm)	44-76 × 24-36 (av. 63.0 × 32.0)	40-71 × 22-34 (av. 52.0 × 28.0)
Chlamydospore		None	None
Hyphal swelling		Common	Sometimes
Cultural pattern	10% V8	Fluffy, aerial	No distinct, fluffy
	PDA	Slightly rosaceous	Slightly floral
Sexuality		Heterothallic	Heterothallic, some self fertile
Oogonium	Shape	Spherical	Spherical
	Size (μm)	24-40 (av. 32.0)	28-38 (av. 33.0)
Oospore	Filling	Plerotic	Pleotic or apleotic
	Size (μm)	20-32 (av. 28.0)	16-37 (av. 28.0)
Antheridium	Type	All amphigynous	Amphigynous
Growth (°C)	Minimum	5	5-10
	Optimum	28	25-30
	Maximum	35	35

[a] Ho and Jong (1986).

Pathogenicity. The fungal isolates caused root rot on kiwifruit seedlings (Table 3). Infected plants defoliated 10 days after inoculation. The same pathogen was re-isolated from infected plants, and severity of root rot varied among isolates.

Discussion

Eight species of *Phytophthora* have been reported to infect kiwifruit in many other countries (Stewart and McCarrisan, 1991; Conn et al., 1991; Latorre et al., 1991; Baudry et al. 1991). In addition, an unidentified *Pythium* species was also known to be associated with the kiwifruit root rot (Conn and Gubler, 1988; Latham and Dozier, 1989).

However, Phytophthora root rot of kiwifruit has not been reported in Korea previously. Results of this study indicate that *P. drechsleri* is the causal organism of kiwifruit root rot in the south coast region of Korea.

According to Jee et al. (2000), *P. drechsleri* is considered one of the five most important major pathogens in the

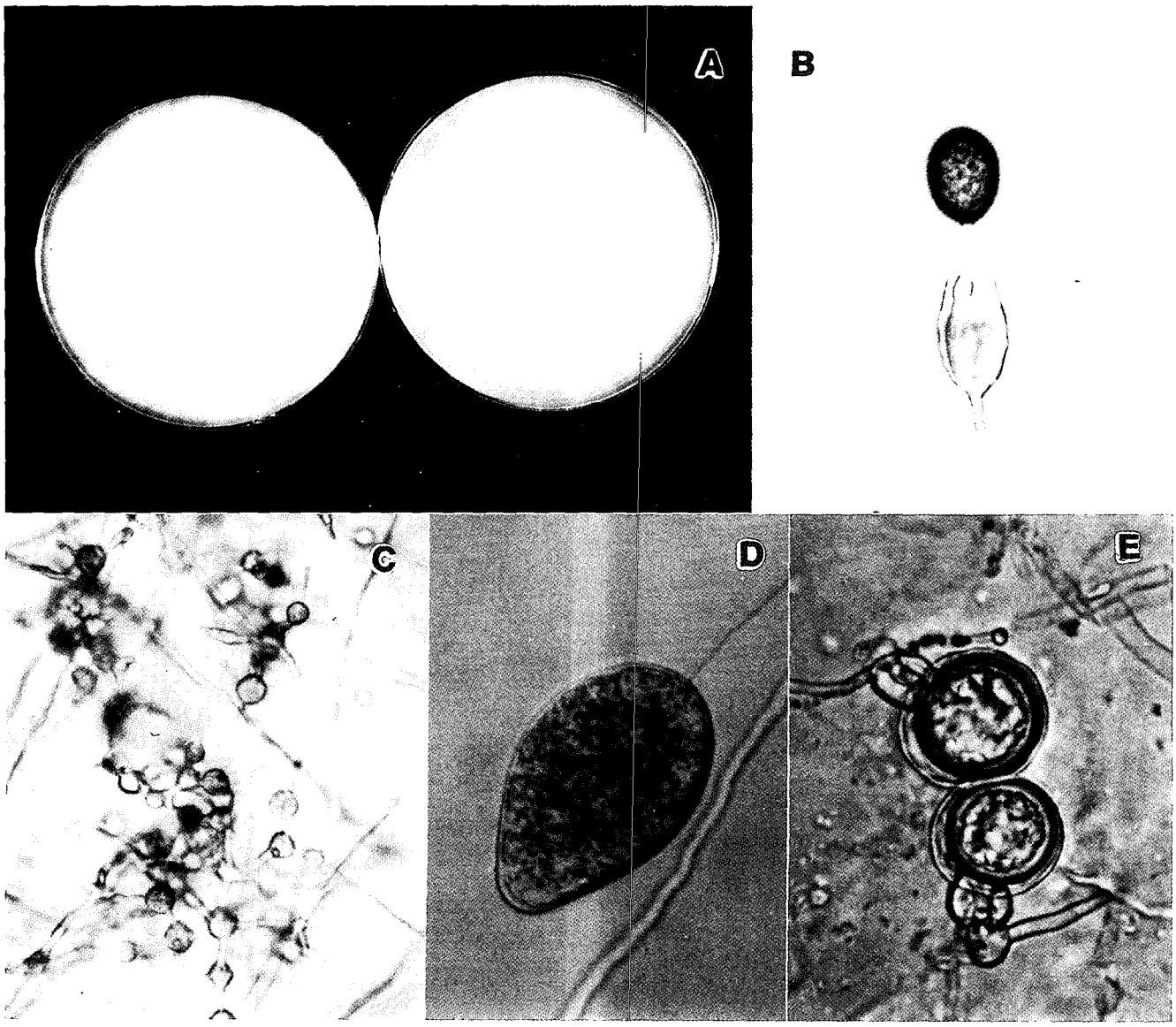

Fig. 2. Morphological characteristics of *Phytophthora drechsleri* which caused root and stem rot of kiwifruit. **A**: Colony patterns of *P. drechsleri* on 10% clarified V8 agar (left) and PDA (right), **B**: An internally proliferated sporangiophore, **C**: Hyphal swelling, **D**: A sporangium formed in water, **E**: Plerotic oospores with amphigynous antheridia.

Table 3. Pathogenicity of kiwifruit isolates of *Phytophtora drechsleri* to kiwifruit seedlings, cv. 'Hayward'

Inoculated isolates	Degree[a] of root rot
PG9701	+++
PG9702	+
PG9703	+
Control	–

[a] Degree: +++, severe; +, weak; –, no symptom.

genus in Korea and has the widest host range. The fungus distributes widely and infects vegetables, medicinal plants, and a few woody plants in the country. However, *P. drechsleri* is not readily distinguishable from *P. cryptogea* morphologically and genetically (Jee et al., 1999). *P. drechsleri* grew at 35°C, but *P. cryptogea* did not (Ho and Jong, 1991). *P. drechsleri* was more virulent to kiwifruit than *P. cryptogea* (Conn et al., 1991). It is believed that further research about the pathogenicity was required to distinguish between *P. drechsleri* and *P. cryptogea*.

Based on its occurrence and pathogenicity of the causal organism, root rot of kiwifruit caused by *P. drechsleri* may be a potential threat to kiwifruit production in Korea, particularly in poorly drained soils such as lowland fields (Table

1). This is probably because the disease was favored by abundant soil moisture (Stewart and McCarrian, 1992; Reid et al., 1991; Conn and Gubler, 1989; Robertson, 1982; Save and Serrono, 1986). Since the disease is often confused with wet feet, it is important to make an exact diagnosis for the control of the root rot disease of kiwifruit.

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