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Severe Root Rot on Hydroponically-Grown Lettuce Caused by *Phytophthora drechsleri*

Hyeong-Jin Jee*, Ki-Woong Nam and Weon-Dae Cho

Plant Pathology Division, National Institute of Agricultural Science and Technology, Suwon 441-707, Korea

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Phytophthora root rot of lettuce, which has not been reported in Korea before, occurred severely in liquid hydroponic culture. The disease occurred in all seasons and was most severe in summer from June to August, showing over 90% infection rate in some farms. A total of 51 isolates collected from various farms were all identified as *Phytophthora drechsleri*. The fungus showed strong pathogenicity to lettuce and Chinese cabbage, moderate pathogenicity to cucurbits and tomato, and weak pathogenicity to pepper. However, the fungus was not pathogenic to other leafy vegetables namely: chicory, kale, endive, garland chrysanthemum, spinach beet, and perilla. Among 10 species of *Phytophthora* inoculated to lettuce, only *P. drechsleri* and *P. cryptogea* were found pathogenic.

Keywords **:** hydroponics, lettuce, *Phytophthora drechsleri*, root rot.

Hydroponic culture is being practiced as a strategy to avoid root diseases and to overcome mono-cropping problems (Jee et al., 2000; Stanghellini and Rasmussen, 1994). In Korea, limited arable land and high demand for fresh vegetables all year round have resulted in an increase in hydroponic culture. This soilless culture began in the country with 10 ha in 1990 and increased drastically to 700 ha in 2000. While tomato, paprika, cucumber, and rose are the main plants being cultivated in aggregated hydroponic system, most leafy vegetables are grown in liquid hydroponic system. Among the leafy vegetables, lettuce is considered to be the most important crop based on economic value and consumption in the country. Under the hydroponic system, its cultivation covers about 40 ha in 2000 (Anonymous, 2000).

Since plants are growing without soil in hydroponics, theoretically, soilborne diseases can be prevented under the system. However, various soilborne pathogens, especially zoosporic fungi *Pythium* and *Phytophthora*, still commonly occur and often cause greater losses than that in soil once introduced into the system (Jee et al., 2000; Stanghellini and Rasmussen, 1994; Zinnen, 1988). In particular, *Phytophthora* is highly destructive in the liquid system because of its strong pathogenicity and rapid reproduction and spread in water as a semi-aquatic fungus (Erwin and Ribeiro, 1996; Jee et al., 2000).

In January 1998, a farmer delivered diseased lettuce samples grown in hydroponics to the National Institute of Agricultural Science and Technology (NIAST) laboratory for diagnosis. *Phytophthora* diseases in lettuce have not been reported in Korea before. However, the fungus was consistently isolated from the diseased plants. A subsequent survey on the disease showed that the Phytophthora root rot of lettuce grown in hydroponics occurred in all seasons and was most severe during summer from June to August. Infection rates of the disease were surprisingly high in most contaminated farms, reaching 30-100% (Table 1). Accordingly, the disease appeared to be the major limiting factor for lettuce production in hydroponics. However, the disease in soil culture has not been observed in Korea yet. Infected plants were severely wilted and eventually died due to the root rot (Figure 1A, B). Main and fine roots of the plant were decayed and inner tissues of the crown were also discolored (Figure 1C, D, E).

A total of 51 isolates of *Phytophthora* were readily isolated from roots or crowns of infected lettuce. All isolates grew well on 10% V8A with slightly aerial mycelia with indistinct rosaceous pattern. The fungus produced sporangia and hyphal swellings only in water. The sporangia, which formed either internally or externally, were all non-

Table 1. Survey on *Phytophthora* root rot of lettuce in hydroponic culture in 1998

Surveyed		Infected area (ha)	Infection rate (%)	No. of isolates collected
Farm location	Month			
Gangdong-gu, Seoul	January	0.4	35-50	6
Tanhyunmeon, Paju	June	2.8	53-90	22
Eunpyung-gu, Seoul	July	1.1	67-100	9
Kangnam-gu , Seoul	August	0.1	30-90	14
Total		4.4	–	51

*Corresponding author.
Phone) +81-31-290-0436, FAX) +81-31-290-0453
E-mail) hjjee@rda.go.kr

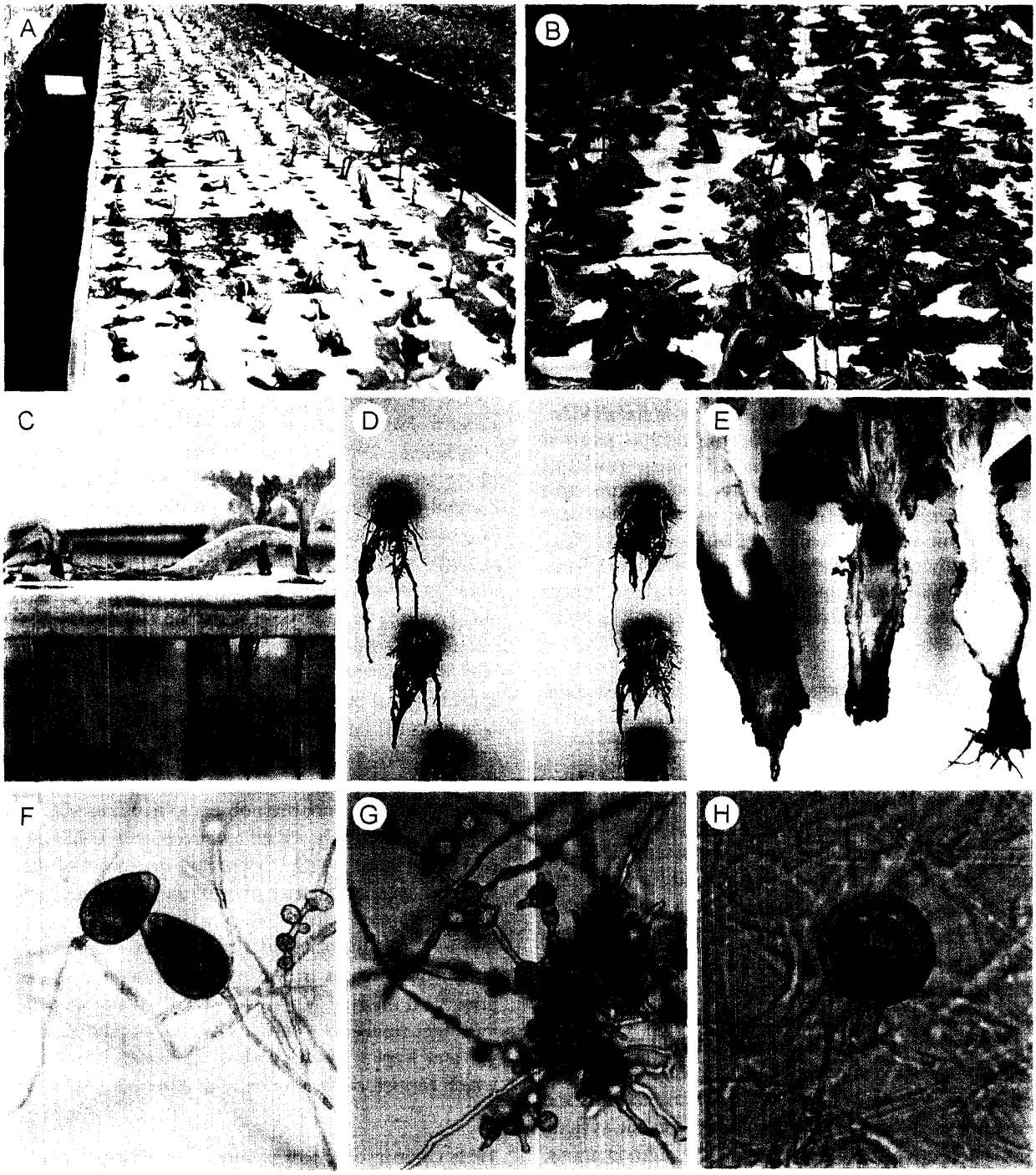

Fig. 1. Symptoms of Phytopthora root rot of lettuce in liquid hydroponic cultures and features of the causal pathogen, *Phytophthora drechsleri*. Heavily infected beds of green-leaf type (**A**) and red-leaf type lettuce (**B**); Severely infected plants on a bed (**C**), decayed roots (**D**), and inner crown tissues (**E**); Sporangia (**F**), hyphal swellings (**G**), and an oospore (**H**) of the pathogen.

papillate, mostly single, ovoid to obpyriform, persistent, round based, and with an average size of 42.3-57.4 × 22.5-30.7 μm (Fig. 1F, Table 2). Rounded or angular hyphal swellings often formed in water with cultural age in chains or clusters (Fig. 1G). The fungus formed oospores only when mated with either A1 or A2 mating standard isolate of *P. drechsleri*. Most oospores filled oogonia and had an average diameter of 29.8-31.5 μm (Table 2). Antheridia were all amphigynous and single celled (Figure 1H). All mycological characteristics of the lettuce isolates were that of *P.*

Table 2. Size of reproduction structures of lettuce isolates of *Phytophthora drechsleri*

Examined Isolate	Average size (μm)			L/B ratio	Mating type
	Sporangium	Oogonium	Oospore		
P-98002	42.3± 8.2 × 22.5±3.8	34.5±4.1	29.8±3.6	1.88	A1
P-98040	54.1±11.5 × 30.7±5.1	36.1±3.2	30.1±5.6	1.76	A2
P-98103	50.4±10.8 × 29.7±3.8	35.6±2.9	30.8±3.3	1.70	A1
P-98170	57.4±14.2 × 29.2±4.5	35.7±3.0	31.5±4.1	1.97	A2
*P. drechsleri**	36-70 × 26-40	22-53(33)	17-50(26)	1.4-2.1	A1/A2

*Described by Erwin and Ribeiro (1996).

Table 3. Pathogenicity of two lettuce isolates of *Phytophthora drechsleri* to various vegetables under hydroponic conditions

Tested vegetable	Degree of root rot*	
	P-9801**	P-9847
Lettuce cv. Red-leaf type	4.0	4.0
Lettuce cv. Green-leaf type	3.3	3.2
Cucumber	2.3	3.3
Tomato	2.2	2.2
Pepper	1.5	0.5
Chicory	0.0	0.0
Kale	0.0	0.0
Endive	0.0	0.0
Garland chrysanthemum	0.0	0.0
Spinach beet	0.0	0.0
Perilla	0.0	0.0

*Degree of root rot was graded as 0 = healthy; 1 = weak; 2 = moderate; 3 = severe; 4 = plant death.

Table 4. Pathogenicity of *Phytophthora* species to lettuce under hydroponic conditions

Phytophthora species	Original host	Degree of root rot*	
		Red-leaf type	Green-leaf type
P. drechsleri	Lettuce	4.0	3.5
P. drechsleri	Tomato	3.3	2.2
P. cryptogea	Gerbera	2.0	1.3
P. cactorum	Apple	0.0	0.0
P. capsici	Pepper	0.0	0.0
P. citricola	Jujube	0.0	0.0
P. citrophthora	Soil	0.0	0.0
P. cinnamomi	Pine	0.0	0.0
P. erythroseptica	Vetch	0.0	0.0
P. nicotianae	Yuzu	0.0	0.0
P. palmivora	Fig	0.0	0.0

*Degree of root rot was graded as 0 = healthy; 1 = weak; 2 = moderate; 3 = severe; 4 = plant death.

drechsleri, as described by the senior author (Jee et al., 1999; 2000), Erwin and Ribeiro (1996), and Stamps et al. (1990).

Phytophthora drechsleri is known as a genetically diverse fungal group in the genus. It cannot be distinguished from *P. cryptogea* because of the morphological similarity of the two fungi. However, Mills et al. (1991) reported that the two species have been combined into an intraspecific group in which at least 10 genetic groups exist. Korean isolates of *P. drechsleri* and *P. cryptogea* were also found to be conspecific based on rDNA RFLP, and four genetic groups subsist in the species complex (Hong et al., 1998, Jee et al., 2000). The fungus is considered as one of the most important species in the genus in Korea because of its wide distribution and host range. Moreover, it is the only species infecting leafy vegetables such as Chinese cabbage and spinach in the country (Jee et al., 1999; 2000).

Two representative lettuce isolates of *Phytophthora* revealed strong pathogenicity to lettuce, moderate pathogenicity to cucumber and tomato, and weak pathogenicity to pepper under hydroponic conditions (Table 3). However, the isolates did not infect other leafy vegetables such as chicory, kale, endive, garland chrysanthemum, spinach beet, and perilla (Table 3). Between the two lettuce cultivars, the red-leaf type was more susceptible than the green-leaf type as observed in the fields. Among 10 species of *Phytophthora* inoculated to lettuce, only *P. drechsleri* and *P. cryptogea* were pathogenic to lettuce, while others did not induce any symptoms on the plant (Table 4).

Although *P. cryptogea, P. drechsleri, P. megasperma,* and *P. porri* have been reported to infect several leafy vegetables such as cabbage, lettuce, spinach, cauliflower, turnip, ratabaga, kale, and Brussels sprouts (Jee et al., 1999; Linde et al., 1990), *Phytophthora* diseases on the plants are considered insignificant in general, and researches on the diseases are rare. However, results obtained in this study indicated that hydroponically-grown Korean cultivars of lettuce are highly susceptible to the pathogen, and that disease epidemics seemed to be closely related to the fungal ecology under the cultural system. High temperature of the nutrient solution during the summer also may play an important role in disease development. The temperature increases up to 24-26°C during the summer in commercial facilities (personal communication with farmers), which

favors the fungal activity but is adverse to lettuce growth. Accordingly, prevention of introduction of the pathogen into the cultural system, regulating the cultural system to become unfavorable for disease development, and cultivating lettuce cultivars resistant to the pathogen are alternative measures to suppress the disease.

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