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Outbreak of Phytophthora Rot on Pear Under Environmental Conditions Favorable to the Disease

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From April to May 1998, Phytophthora rot on pear, which has not been reported in Korea before, became an epidemic in the southeast part of the country under abnormally higher temperature and prolonged rainy days. Average temperature was about 3°C higher than in normal years, and 29 days were rainy during the 2 months in the areas surveyed. Over 1,000 orchards estimated at about 270 ha in 19 cultivation areas were infected by the disease, which occurred on all parts of the tree such as leaves, shoots, branches, stems, and flower clusters. Among 43 isolates collected from various locations and plant parts, 41 were identified as *Phytophthora cactorum* while 2 were identified as *P. cambivora* based on their mycological characteristics. The representative isolates revealed strong pathogenicity not only to pear but also to apple and peach. Among 23 pear cultivars tested, 7 were estimated as susceptible, 4 were moderate, and 11 were resistant to the pathogen. Results suggest that Phytophthora disease on pear is a potential threat to pear cultivation when environmental factors are favorable to disease development.

Keywords : environmental factors, pear, *Phytophthora cactorum, P. cambivora*, rot.

Pear is one of the most important fruit tree in Korea based on its economic value and practical use. As it has over 1000 years of cultivation history in the country, 21 biological agents are known to cause various diseases on the tree (The Korean Soc. Plant Pathol., 1997; 1998). Several *Phytophthora* species are known to infect pear in many growing areas worldwide, although the fungal disease on pear is considered of minor importance in general (Grove and Boal, 1991), and has never been reported in Korea before (The Korean Soc. Plant Pathol., 1997; 1998).

However, sporadic outbreak of *Phytophthora* diseases on pear results to serious damage when environmental factors are favorable to disease development (Jeffers and Wilcox, 1990; Jeffers and Aldwinckle, 1986). Temperature and wetness duration largely affect *Phytophthora* infection (Grove and Boal, 1991). Over-tree irrigation with sprinklers often cause severe rot on immature pear fruit, thus, the disease has been called as sprinkler rot (Grove and Boal, 1991; Covey and Harris, 1990).

In Korea, Phytophthora collar rot on pear was first observed in Seosan in 1997 by the authors. The disease severely occurred mainly on the basal stems of 1- to 2-year-old young trees. Among 43 pear orchards surveyed in the area, 40 fields were infected by the disease. Disease incidence was lower than 5% in most fields. However, a few fields showed over 50% infection rate. In 1998, with environmental factors favoring disease development, Phytophthora rot on pear became an epidemic in the southeast part of Korea, particularly in Ulsan area. The disease spread rapidly on all parts of the tree such as leaves, shoots, branches, flower clusters, and stems.

In this paper, Phytophthora disease on pear is first reported in Korea based on the result of the disease survey throughout the country. Identification of the causal pathogen, along with its pathogenicity test to 23 pear cultivars, was also determined.

Materials and Methods

Disease survey and pathogen isolation. A survey on Phytophthora diseases on pear was conducted in 1998 throughout the country in cooperation with extension workers of the Rural Development Administration, Korea. The plant was considered as infected by the pathogen only when *Phytophthora* sp. was isolated from rot lesions. Pathogens were isolated from leaves, flower clusters, branches, or stems showing irregularly large brownish rots. Infected tissues were cut into small pieces and placed on *Phytophthora* semi-selective medium and water agar (WA) after a short disinfection process with 1% NaOCl. The semi-selective medium consisted of corn meal agar (CMA; Difco, 17 g/l) and was supplemented with pimaricin 10 μg/ml, rifampicin 10 μg/ml, ampicillin 100 μg/ml, and PCNB 50 μg/ml (Jee et al., 2000).

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Identification of pathogen. To examine the morphological characteristics of asexual reproduction structures, isolates were cultured on 10% V8A for 3-4 days at 24°C and cut into agar discs by a cork borer (6 mm in diameter). After transferring the agar disc to a concave slide (0.5 × 15 mm in hole depth and diameter), 0.5 ml of distilled water was placed into the hole to submerge the disc. Sporangia that formed on the disc were examined after incubation at 24°C for 24 h under light. Since most isolates, except two, readily formed oospores by single culture, they were considered as homothallic species. Oospores of the homothallic isolates were observed directly from the cultures. To induce oospore formation of the two heterothallic isolates, both A1 and A2 mating types of *P. cryptogea* and *P. drechsleri* were used as described previously (Jee et al., 1997b). The pear isolates and the standard mating type isolates were grown for 5-7 days on 20% V8A. The cultures were cut by a cork borer (10 mm in diameter) and six agar discs of a pear isolate were evenly distributed on a petri plate. A sterilized polycarbonate (PC) membrane (90 mm, 0.2 μm, Nucleopore Co., USA) was placed on top of the agar discs. Each two agar discs of A1 and A2 mating types were laid upside down on top of the testee discs. The rest of the discs remained in the PC membrane. After incubation at 20°C for 2 weeks in the dark, the PC membrane was removed along with the top discs, and oospores that formed at the bottom of the testee discs were examined under a microscope at 100× or 200×.

Pathogenicity test. Two isolates each of *P. cactrum* and *P. cambivora*, and one isolate each of *P. citricola* and *P. citrophthora* were used for the pathogenicity test to 3-year-old pear, apple, and peach. Isolates grown on 10% V8 agar for 5 days were cut into discs with a cork borer (6 mm in diameter). Bark on stem of the trees was excised with the same size as the cork borer. An agar disc was attached to the wound and sealed with parafilm. Rot lesions that developed 10 days after inoculation were measured. Susceptibility of 23 pear cultivars to *P. cactorum* was also evaluated. Young branch cuttings of the cultivars were sprayed with zoospore suspension (about 10^4/ml) and incubated in a growth chamber for 3 days. Degree of leaf rot was estimated based on infected leaf area from a scale of 0 to 4. Fifteen to 25 leaves from three cuttings of each cultivar were examined individually. Three replicates were used for the pathogenicity test and the experiments were repeated once.

Results

Disease survey and symptoms. From the survey conducted in 1998, the *Phytophthora* disease on pear was observed in 1076 orchards in 19 cultivation areas with an estimated infected area of about 271.6 ha (Table 1). The disease severely occurred in the southeast part of Korea, namely Ulsan, Kijang, and Sangju. In these areas, Phytophthora rot developed in all aerial parts of tree such as leaves, shoots, branches, flower clusters, and stems (Fig. 1).

Phytophthora collar rot on pear occurred commonly on 1- to 2-year-old young trees. However, disease on adult trees was observed in only one field in Sangju, Kyungbuk province. Heavily infected trees showed leaf yellowing and loss of vigor (Fig. 1A). In young pear trees, light to dark brownish collar rot appeared on the basal stem (Fig. 1B). Irregular large brown rots developed on stems, branches, and flower clusters (Fig. 1C, D, E, F). The pathogen also caused shoot blights and leaf rots in the fields (Fig. 1G, H).

Environmental conditions. The average temperature in April and May of 1998 in Ulsan area, in which the Phytophthora rot on pear was most severe, was 2.5-3.0°C higher than that in normal years of 15.4 and 20.3°C, respectively. It rained almost every other day during the 2 months, recorded as 14 and 15 days, respectively. Average rainy days in that area in normal years were only 7.5 and 9.4 days, respectively (Table 2).

Characterization of isolates. A total of 43 isolates were collected from various regions and plant parts (Table 1). Forty-one isolates were identified as *Phytophthora cactorum*, while two were identified as *P. cambivora* based on their mycological characteristics. Morphological characteristics of present isolates were compared with the species

Table 1. A survey on *Phytophthora* rot on pear from May to June of 1998 in Korea

Province	Infected			Severity of rot[a]			No. of isolates collected
	Area (no.)	Orchard (no.)	Acreage (ha)	Collar rot		Aerial parts	
				1-2 yr.	>3 yr.		
Kyunggi	6	13	2.0	++	−	−	8
Kangwon	2	6	0.2	+	−	+	0
Chungnam	1	6	0.2	++	−	−	6
Junbuk	6	11	3.2	++	−	−	4
Kyungbuk	1	12	0.9	++	++	++	5
Pusan	1	58	53.7	+	−	+++	12
Ulsan	1	992	219.1	+	+	+++	8
Total	19	1,076	271.6				43

[a] Severity of rot: −: no; +: weak; ++: moderate; +++: severe.

Fig. 1. Symptoms of Phytophthora rot on pear by *P. cactorum* or *P. cambivora*. (**A**) Heavily infected adult tree, (**B**) Collar rot on a young tree, (**C, D**) Severe stem rots and inner tissues, (**E, F**) Infected flower clusters, (**G**) Infected shoot showing blight, (**H**) Irregular large leaf spot developed by the pathogen in fields.

descriptions of Erwin and Ribeiro (1996), Jee et al. (2000), and Stamps et al. (1990). The former species was well characterized by its markedly papillate, ovoid, and highly deciduous sporangia with short pedicles. As the species is homothallic, it readily formed oospores on 10% V8 agar by single culture. Oospores were plerotic and all antheridia were paragynous.

The latter species belongs to *Phytophthora* group VI since it produced non-papillate sporangia and does not form oospores by single culture (Stamps et al., 1990). It pro-

Table 2. Comparison between environmental conditions in Ulsan area in 1998 and in normal year

Factor	April		May	
	1998	'61-'90	1998	'61-'90
Temp (°C)	15.4	12.9	20.3	17.3
RH (%)	75.9	67.0	69.6	70.0
Rainfall (mm)	259.7	147.6	98.5	148.1
Rainy day	14	7.5[a]	15	9.4[a]

[a]Mean of 10 years from 1988 to 1997. All data were obtained from the Korea Meteorological Administration.

duced non-papillate ovoid to obpyriform sporangia only in water internally or externally. However, the sporangial morphology cannot be the decisive characteristics of the species in the group. On the other hand, the fungus was clearly distinguishable from other species by the unique features of its oospores. It formed oospores only when paired with A2 mating types of standard cultures and some of the oogonial walls were bulleted. Oospores were plerotic and antheridia were all amphigynous. Most antheridia were one-celled, although a few two-celled were also observed. These characteristics were consistent with that of *P. cambivora* described by the author (Jee et al., 1997b) and others (Erwin and Ribeiro, 1996; Stamps et al., 1990).

Pathogenicity. All tested isolates of *Phytophthora cactorum, P. cambivora, P. citricola,* and *P. citrophthora* were pathogenic not only to pear but also to apple and peach at varying degrees (Table 3). Between two isolates of *P. cactorum*, an apple isolate showed stronger pathogenicity than the pear isolate to the fruit trees. However, a pear isolate of *P. cambivora* showed much higher pathogenicity to the trees than the apple isolate. The rot lesions that developed for 10 days varied from 2 to 31.5 mm depending on the cultivars or isolates (Table 3).

Among 23 pear cultivars tested, cvs. Chuwhangbae and Soowhangbae were the most susceptible to *P. cactorum*. Rot lesions that developed on leaves of the cultivars were over 40% (Table 4). Five cultivars namely Hosui, Yeongsanbae, Shinseiki, Shinko, and Niitaka were also susceptible to the pathogen showing over 20% rot areas on leaves. Meanwhile, cvs. Shunhwang Chojuro, Mansoo, Shinsui, Mangpoongbae, Whangkeumbae, Wonwhang, Okusankichi, Minibae, Whasan, and Mihwang were resistant showing less than 5% rot lesions on the leaves (Table 4).

Table 4. Estimated susceptibility of pear cultivars to *Phytophthora cactorum*

Pear cultivar	Degree of leaf rot[a]	Estimated susceptibility
Chuwhangbae	4.00 Z[b]	SS
Soowhangbae	4.00 Z	SS
Hosui	3.83 Z	S
Yeongsanbae	3.42 YZ	S
Shinseiki	3.13 YZ	S
Shinko	3.12 YZ	S
Niitaka	3.10 YZ	S
Gamcheonbae	2.95 YZ	S
Kosui	2.53 Y	M
Shinil	2.50 Y	M
Imamuraaki	2.22 Y	M
Gamro	1.62 XY	M
Sunhwang	0.75 X	R
Chojuro	0.68 X	R
Mansoo	0.57 WX	R
Shinsui	0.55 WX	R
Manpoongbae	0.53 WX	R
Whangkeumbae	0.46 WX	R
Wonwhang	0.33 WX	R
Okusankichi	0.19 WX	R
Minibae	0.14 WX	R
Whasanbae	0.09 W	RR
Mihwang	0.07 W	RR

[a]Mean value of leaf rot: 0=0; 1=0.1-5%; 2=6-20%; 3=21-40%; 4=over 40% of leaf area was rotten. Fifteen to 25 inoculated leaves of each cultivar were individually calculated.
[b]Different letters in a column were significantly different at 5% level by Tukey-Kramer Honestly Significant Different (HSD).

Table 3. Pathogenicity of *Phytophthora* species to fruit trees by wound inoculation on stem

Species	Origin	Rot lesions developed on stem (/10 days)					
		Pear		Apple		Peach	
		Niitaka	Wonwhang	Fuji	Hongro	Hakuto	Yumyeung
P. cactorum	Pear	2.0	7.5	3.0	2.0	10.5	10.0
P. cactorum	Apple	20.0	21.0	11.0	11.0	30.0	31.5
P. cambivora	Pear	21.0	32.0	10.5	21.5	16.5	3.0
P. cambivora	Apple	14.0	12.5	7.0	8.5	13.0	6.5
P. citricola	Jujube	2.5	8.5	5.3	4.5	6.0	8.0
P. citrophthora	Soil	19.0	7.5	2.7	12.5	7.5	3.0

Discussion

In general, Phytophthora disease on pear is considered of minor importance, and has never been reported in Korea before. However, an outbreak of the disease in the southeast part of Korea in 1998 suggested that the disease is a potential threat to pear production in the country when environmental factors are favorable to disease development. According to Grove and Boal (1991), wetness duration and temperature largely affect *P. cactorum* infection to apple and pear fruits. The unusual high temperature and prolonged rainy days during the actively growing season in the areas played key roles in the disease epidemic.

Susceptibility of aboveground parts of apple and pear to *Phytophthora* is known to fluctuate seasonally (Jeffers and Wilcox 1990; Sewell and Wilson, 1973). It is relatively low during tree dormancy and increases to a peak during early spring to summer (Jeffers and Aldwinckle, 1986). However, highly caducous sporangial characteristics of *P. cactorum* and rain slash or storm which disseminate the pathogen to the aerial parts of the tree are the key factors for the aerial disease development.

Among several species of *Phytophthora* infecting pear, *P. cactorum* and *P. syringae* are the major pathogens, although other species are locally significant (Harris, 1991). *P. syringae* is known as a major pathogen on pear and apple in northwestern Europe. However, it has never been found yet in Korea (Jee et al., 2000). Meanwhile, *P. cactorum* is distributed widely in Korea and is considered one of the most important pathogens in the genus (Jee et al., 2000). This pathogen was reported as the major pathogen of apple Phytophthora rot, which was an epidemic in 1996 in the country (Jee et al., 1997a, b). The disease on apple, similar to that on pear, also developed on all parts of the tree, especially on immature fruits and basal stems. Another causal pathogen, *P. cambivora*, was also reported on apple causing similar diseases by the authors (Jee et al., 1997b). This species caused similar symptoms with *P. cactorum*, and showed strong pathogenicity to pear, apple, and peach. However, the fungus was not significant on trees because of its low isolation frequency and distribution in the country (Jee et al., 2000; Jee et al., 1997b).

Pear is considered less susceptible to *Phytophtora* than apple (Covey and Harris, 1990; Harris, 1991). However, Grove and Boal (1991) reported that *P. cactorum* infected fruits of pear and apple within 3-5 h at 15-30°C, and that the infection increased with increased wetness duration and temperature of up to 28°C. In addition, 12 pear cultivars among 23 tested in this study were evaluated as susceptible or moderate to *P. cactorum*. The rot lesions developed rapidly on pear cultivars by wound inoculation, and the Phytophthora collar rot on young pear trees was commonly observed in most cultivation areas. Consequently, results of this study showed that pear is not safe from *Phytophthora*, and that the disease could be a potential threat to pear cultivation under favorable environmental conditions.

References

Browne, G. T. and Mircetich, S. M. 1996. Effects of month inoculation on severity of disease caused by *Phytophthora* spp. in apple root crowns and excised shoots. *Phytopathology* 86:290-294.

Covey, R. P. and Harris, D. C. 1990. Phytophthora fruit rot. In: *Compendium of Apple and Pear Diseases*. A. L. Jones and H. S. Aldwinckle, eds. APS, St. Paul, MN. pp. 30-31.

Erwin, D. C. and Ribeiro, O. K. 1996. *Phytophthora Diseases Worldwide*. APS press, St. Paul. Minn., 562 p.

Grove, G. G. and Boal, R. J. 1991. Influence of temperature and wetness duration on infection of immature apple and pear fruit by *Phytophthora cactorum*. *Phytopathology* 81:1465-1471.

Harris, D. C. 1991. The Phytophthora diseases of apple. *J. Hort. Sci.* 62:441-447.

Jee, H. J., Cho, W. D. and Kim, W. G. 1997a. *Phytophthora* diseases of apple in Korea : I. Occurrence of a destructive collar rot caused by *P. cactorum*. *Korean J. Plant Pathol.* 13:139-144.

Jee, H. J., Cho, W. D. and Kim, W. G. 1997b. *Phytophthora* diseases of apple in Korea: II. Occurrence of an unusual fruit rot caused by *P. cactorum* and *P. cambivora*. *Korean J. Plant Pathol.* 13:145-151.

Jee, H. J., Cho, W. D. and Kim, C. H. 2000. *Phytophthora Diseases in Korea*. National Institute of Agricultural Science and Technology, Rural Development Administration, Suwon, Korea. 226 pp.

Jeffers, S. N. and Aldwinckle, H. S. 1986. Seasonal variation in extent of colonization of two apple rootstocks by five species of *Phytophthora*. *Plant Dis.* 70:941-945.

Jeffers, S. N. and Wilcox, W. F. 1990. *Phytophthora* crown, collar and root rots. In: *Compendium of Apple and Pear Diseases*, ed by A. L. Jones and H. S. Aldwinckle, pp. 43-45. APS, St. Paul, MN.

Sewell, G. W. F. and Wilson, J. F. 1973. Phytophthora collar rot of apple: Seasonal effects on infection and disease development. *Ann. Appl. Biol.* 74:149-158.

Stamps, D. J., Waterhouse, G. M., Newhook, F. J. and Hall, G. S. 1990. Revised tabular key to the species of *Phytophthora*. *Mycological Papers* No. 162.

The Korean Society of Plant Pathology. 1997. *Apple and Pear Diseases and Their Control*. Suwon, Korea. 227 pp. (in Korean).

The Korean Society of Plant Pathology. 1998. *List of Plant Diseases in Korea* 3rd ed. Suwon, Korea. 436 pp. (in Korean).