EXOTIC PLANT PATHOGENS IN JAPAN

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Summary

Various exotic plant pathogens entered Japan before the country's plant quarantine system was established in 1914. The recent expansion of international trade has once more made the risk of invasion by exotic diseases a potentially serious problem. New pathogen species and new pathogen strains can both damage crops and reduce production because the new strains cause a breakdown of resistance in resistant cultivars and can decrease pesticide efficacy. Identification of the new pathogens using molecular techniques is necessary to support disease management strategies. Outbreaks of *Phytophthora infestans* (Montagne) de Bary and *Tomato yellow leaf curl virus* are described.

1. Introduction

Exotic plant pathogens in Japan have a history of more than 100 years. Japan opened several ports to foreign trade in 1859, and since then, breeders and farmers have imported seedlings of new crops and new cultivars. Several plant pathogens were also introduced unintentionally. The first Japanese plant pathologists, who appeared as a profession in the 1880s, described these new plant diseases. Exotic plant pathogens such as *Phytophthora infestans* (Montagne) de Bary and *Agrobacterium tumefaciens* (Smith and Townsend 1907) Conn 1942 had been reported before the Japanese plant quarantine service was started in 1914 (Table 1).

Recently, the risk of invasions by exotic plant pathogens has once again become serious because the amount of imported agricultural products, and especially of fresh fruits and vegetables, and the seedlings of ornamental plants, have been increasing. Quarantine inspection detected 10 bacterial and 73 fungal pathogens in plant materials imported in 2002 alone (Plant Protection Station, 2002); this corresponds to increase of 167 and 197%, respectively, compared with the levels reported in 1997. Although most of the pathogens detected by this inspection were the same species that were already present in Japan, the data suggest an increased probability of invasion by new pathogen strains as well as by new pathogen species.

Both new species and new strains can do considerable damage to agricultural crops. New strains that differ from the native or old strains in their pathogenicity or sensitivity to pesticides can overcome resistance in resistant cultivars and can decrease pesticide efficacy. Moreover, genetic exchange between old and new strains might result in "superstrains" with unusually high virulence. Consequently, accurate identification of the pathogen strain is necessary to support disease management strategies. Recent advances in molecular techniques have enabled the genetic analysis of pathogen strains. In this report, outbreaks of *P. infestans* and *Tomato yellow leaf curl virus* (TYLCV) are discussed.

2. Invasive plant pathogens introduced into Japan

(1) *Phytophthora infestans*

Phytophthora infestans is the fungus that causes late blight of potato (*Solanum tuberosum* L.) and tomato (*Lycopersicon esculentum* Mill.). The fungus entered Japan at the beginning of the 20th century (Kusano, 1901; Nomura, 1901) and became one of the most common pathogens of the potato in Japan (Japan Plant Protection Association, 2003). *Phytophthora infestans* is a heterothallic oomycete with two mating types, designated A1 and A2. Before the 1980s, only the A1 mating type had been found in populations of *P. infestans* outside of Mexico (Fry et al., 1992). These A1 isolates belonged to a single genotype, US-1 (Goodwin et al., 1994). However, the A2 mating type has been isolated in Europe (Hohl and Iselin, 1984), North America (Goodwin et al., 1994), and Japan (Mosa et al., 1989) since the 1980s.

The new Japanese A2 isolates, assigned to genotype JP-1, were distinguished from US-1 and other new genotypes in Europe and North America based on their allozyme loci, nuclear DNA fingerprints and mitochondrial DNA haplotypes (Mosa et al., 1993; Therrien et al., 1993; Koh et al., 1994). Genotype JP-1 has also been found in Korea (Koh et al., 1994), and the A2 mating type became dominant in both Korea and Japan in the early 1990s (Kato et al., 1998b; Nishimura et al., 1999). Although tolerance to metalaxyl and pathogenicity to resistant potato cultivars were noted among A2 isolates (Therrien et al., 1993; Kato et al., 1994), the mechanism of the population change is not clear.

In the late 1990s, new *P. infestans* populations were found in Japan. New A1 isolates that differed from US-1 appeared in Hokkaido (Kato and Naito, 1997) and Kyushu (Sayama et al., 2003). One of the genotypes of the new A1 isolates was identified as He-Gan A1-A, which was also found in China and other countries in northern Eurasia (Akino et al., 2004). Because A1-A isolates have shown metalaxyl resistance (Kato and Naito, 1999) and high infectivity (Kato and Naito, 1998), international research on this genotype is necessary.

(2) *Tomato yellow leaf curl virus*

The first occurrences in Japan of TYLCV were in the Tokai area (Shizuoka and Aichi Prefectures) and on Kyushu (Nagasaki Prefecture) in 1996 (Onuki et al., 1997; Kato et al., 1998a; Table 2). The nucleotide sequences of the genomic DNA of TYLCV collected from Shizuoka (TYLCV-Sz) and from Nagasaki (TYLCV-Ng) showed 92% similarity, indicating that both strains probably belong to the same species.

However, these two strains seemed to have different origins, because TYLCV-Sz exhibited higher similarity (98%) to the mild isolate of TYLCV collected from Israel (TYLCV-Is-M), whereas TYLCV-Ng shared 98% identity with the regular isolate of TYLCV from Israel (TYLCV-Is) (Onuki et al., 2004). The two strains also differed in their pathogenicity to the russell prairie gentian (*Eustoma grandiflorum* (Raf.) Shinn) and zinnia (*Zinnia elegans* Jacq.) (Onuki et al., 2004).

3. Discussion & Conclusions

It is often difficult to identify pathogen strains purely based on morphological observations. New strains must thus be characterized based on their pathogenicity, on physiological tests, or on molecular markers, and for this reason, it is necessary to accumulate information on the pathogenic strains that are present in a country. Developing international databases and culture collections will be an essential tool in investigating the genetic variety of plant pathogens and their spread around the world.

A genetic marker database for *P. infestans* has been compiled by Forbes et al. (1998), and is now available on the Internet (http://mgd.nacse.org/cgi-bin/hyperSQL_gateway/?/hyperSQL/phytoph/hsql/phin.hsql). A collection of *P. infestans* isolates are maintained at Cornell University, but the university stopped adding new cultures in the late 1990s (W. E. Fry, Cornell

University, personal communication). It is important to continue funding such programs to improve the databases and culture collections that are available to researchers.

The prevention and quick detection of the new pathogen strains would decrease the cost of disease management. Information exchange on exotic plant pathogens by means of databases, collections, and other tools would benefit both countries in which the pathogens have become established and countries that have not yet been invaded by the pathogen.

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Table 1. Plant pathogens introduced into Japan before 1914.

Group: fungi

Name: *Phytophthora infestans* (Montagne) de Bary

(Family: Pythiaceae, Order: Pythiales)

English name: potato late blight fungus

Year of invasion: 1900

Native region: Central and South America

Situation of establishment: settled before 1950

Similar species: none

Expansion of distribution area: *Phytophthora infestans* overwinters as mycelium in potato tubers. Domestic trade of tubers for seed aids the dispersal of *P. infestans.*

Habitat: vegetable field

Host species: potato (*Solanum tuberosum* L.), tomato (*Lycopersicon esculentum* Mill.), eggplant (*Solanum melongena* L.), and other *Solanum* spp.

Environmental impact: unknown

Economic damage: About 29.2% of potato fields (26 874 ha) were infected in 2002.

Reproduction: Primary infection is caused by diseased tubers. Further spread takes place by airborne or waterborne sporangia.

Growth: Field infection is most successful under cool, moist conditions. Production of sporangia is most rapid at 100% relative humidity and at 21°C.

Countermeasure: Chemical control by means of metalaxyl, oxadixyl, fluazinam, chlorothalonil, maneb, or mancozeb is available. Use of blight-free seed potatoes and resistant cultivars is recommended where possible.

Reference: Kusano (1901), Nomura (1901)

Group: fungi

Name: *Plasmopara viticola* (Berkeley & Curtis) Berlese & de Toni

(Family: Peronosporaceae, Order: Peronosporales)

English name: downy mildew fungus of grapes

Year of invasion: 1890

Native region: North America

Situation of establishment: settled before 1950

Similar species: none

Expansion of distribution area: *Plasmopara viticola* is disseminated with plants.

Habitat: fruit orchard

Host species: European grape (*Vitis vinifera* L.) and fox grape (*Vitis labrusca* L.)

Environmental impact: unknown

Economic damage: About 21.5% of fields (4 488 ha) were infected in 2002.

Reproduction: *Plasmopara viticola* overwinters mainly as oospores in fallen leaves. Oospores germinate in spring to produce sporangia from which primary dispersal of zoospores occurs by means of rain-splash.

Growth: Production of sporangia requires 95 to 100% relative humidity and 4h of darkness. The optimal temperature for sporulation is 18 to 22°C.

Countermeasure: Chemical control by means of Bordeaux mixture, metalaxyl, oxadixyl, or fosetyl is available.

Reference: Tanaka (1890), Shirai (1891)

Group: fungi

Name: *Uncinula necator* (Schweinitz) Burrill [*Oidium tuckeri* Berkeley]

(Family: Erysiphaceae, Order: Erysiphales)

English name: powdery mildew fungus of grapes

Year of invasion: 1891

Native region: North America

Situation of establishment: settled before 1950

Similar species: none

Expansion of distribution area: *Uncinula necator* is disseminated with plants.

Habitat: fruit orchard

Host species: European grape (*Vitis vinifera* L.) and fox grape (*Vitis labrusca* L.)

Environmental impact: unknown

Economic damage: 676 ha of fields were infected in 1994.

Reproduction: *Uncinula necator* overwinters as hyphae inside dormant buds or as cleistothecia on the surface of the grapevine. In spring, the fungus is reactivated and covers the emergent shoots with mycelium and conidia. The conidia are disseminated by wind to neighboring vines.

Growth: Temperatures of 20 to 27°C are optimal for infection and disease development.

Countermeasure: Chemical control by means of benomyl, thiophanatemethyl, or triflumizole is available.

Reference: Shirai (1891)

Group: bacteria

Name: *Agrobacterium tumefaciens* (Smith & Townsend 1907) Conn 1942

(Family: Rhizobiaceae, Class: Proteobacteria, Alpha subclass)

English name: crown gall pathogen

Year of invasion: 1890

Native region: Europe

Situation of establishment: settled before 1950

Similar species: none

Expansion of distribution area: *Agrobacterium tumefaciens* is disseminated with plants or soil.

Habitat: fruit orchard

Host species: stone fruits (*Prunus* spp.), pome fruits (*Malus* spp. and *Pyrus* spp.), roses (*Rosa* spp.), and a very wide range of dicotyledons.

Environmental impact: unknown

Economic damage:

Reproduction: *Agrobacterium tumefaciens* is present in the soil and the roots of host plants. The infection is initiated at wounds on fruit trees.

Growth: Galls may be obvious 2 to 4 weeks after infection when temperatures are above 20°C.

Countermeasure: Biological control using *Agrobacterium radiobacter* (Beijerinck and van Delden 1902) Conn 1942 is available. Soil fumigation with dazomet is effective to some extent. Use of disease-free plants is recommended.

Reference: Ministry of Agriculture and Commerce (1923)

Table 2. Plant pathogens introduced into Japan since the 1990s.

Group: virus

Name: *Tomato yellow leaf curl virus* (TYLCV)

(Genus: *Begomovirus*, Family: *Geminiviridae*)

English name: tomato yellow leaf curl virus

Year of invasion: 1996

Native region: Mediterranean area

Situation of establishment: settled after 1951

Similar species:

Expansion of distribution area:

Habitat: greenhouse / hothouse

Host species: tomato (*Lycopersicon esculentum* Mill.)

Environmental impact: unknown

Economic damage:

Reproduction: transmitted by the whitefly (*Bemisia argentifolii* Bellows & Perring = *B. tabaci* biotype B)

Growth:

Countermeasure: Chemical control by means of imidacloprid, etofenprox, or pyridaben is effective in controlling the whitefly vector.

Reference: Onuki et al. (1997), Kato et al. (1998a)
