United States Department of Agriculture

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Animal and Plant Health Inspection Service

Plant Protection and Quarantine

NPAG Report
Phytophthora chrysanthemi Naher, Hi. Watan., Chikuo & Kageyama: Crown and root rot of chrysanthemum

Pythiales: Pythiaceae

NPAG Chair Approval Date: April 1, 2016

Plant decline and death caused by *P. chrysanthemi* in field-produced chrysanthemums for cut flowers in Croatia. Photo courtesy of Zeljko Tomic, Croatian Centre for Agriculture, Food and Rural Affairs, Institute for Plant Protection

New Pest Advisory Group
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Synonyms: None.

Pest Situation Overview:

Exotic status: A newly described species (Naher et al., 2011), *P. chrysanthemi* had only been reported from Japan (Naher et al., 2011) and Croatia (Tomic and Ivic, 2015; Jung et al., 2015).

Prevalence and global distribution: Asia – Japan (Gifu and Toyama prefectures) (Naher et al., 2011); **Europe** – Croatia (Pond (Karlovac), Jakovlje, Kloštar Ivanić, Stružec (Popovača) and Pula) (Tomic and Ivic, 2015; Jung et al., 2015).

Host range: Asteraceae – *Chysanthemum* × *morifolium* (Naher et al., 2011), *Chrysanthemum* sp. (Naher et al., 2011; Jung et al., 2015).

Phytophthora chrysanthemi was isolated and confirmed on *Chrysanthemum* hybrid 'Aubrey Gold' in the United States (Bowers, 2016).

Biology*: Phytophthora chrysanthemi* is an oomycete, a fungus-like organism that reproduces sexually through oogonia and asexually through chlamydospores, sporangia, zoospores, and mycelia (Naher et al., 2011). Chlamydospores and oogonia are often the survival structures for *Phytophthora* spp. (Erwin and Ribeiro, 1996), but their role in the life cycle of *P. chrysanthemi* is unknown. *Phytophthora chrysanthemi* is tolerant of high temperatures, with optimum growth in culture at 30°C and growth still occurring at 35°C (Naher et al., 2011; Yang et al., 2014). It belongs to a small cluster of *Phytophthora* species in Clade 9 that have been called "high-temperature tolerant" (Yang et al., 2014).

Phytophthora chrysanthemi causes stem and root rot of chrysanthemums. In Croatia, the initial symptoms observed were growth retardation and deterioration; infected plants were several times shorter than healthy plants, which were also greyish-green in color and were concentrated in a part of the "tunnel" with standing water (holding water) (Tomic and Ivic, 2015). In one location, the stem and root rot were only noted once these small plants were removed from the soil (Tomic and Ivic, 2015). A large amount of damage from *P. chrysanthemi* was observed in some of surveyed greenhouses and "it is certain that this [pathogen] has significant infectious potential" (Tomic and Ivic, 2015).

Naher et al. (2011) observed stem and root rot in both chrysanthemums for cut flowers and in hydroponically grown potted chrysanthemums produced in an ebb and flow mat irrigation system. Variation in damage levels was reported among chrysanthemum cultivars used for testing Koch's postulates: all were infected and exhibited symptoms, but the rate of movement up the steams varied among the three cultivars tested. Infected portions became black and wilted, followed by death of the plants (Naher et al., 2011).

In the recent detection in the United States, 15 percent of 300 plants were symptomatic (plant death or decline) and replaced with new plants (Burch, 2016e; Burch, 2016b). It is not clear if these original cuttings were the source of the pathogen or if the pathogen had been previously introduced in the planting bed, though symptoms did not occur in the replacement plants supplied by a different grower (Burch, 2016a).

Known pest status: Infection by *Phytophthora chrysanthemi* can result in small, unmarketable plants and plant death, reducing both cut flower and potted plant yields (Naher et al., 2011; Tomic and Ivic, 2015). *Phytophthora chrysanthemi* has caused stem and root rot of chrysanthemums in both Japan and Croatia (Naher et al., 2011; Tomic and Ivic, 2015). A large amount of damage from *P. chrysanthemi* was observed in some of surveyed greenhouses and "it is certain that this [pathogen] has significant infectious potential" (Tomic and Ivic, 2015), though damage has not been quantified. Naher et al. (2011) observed stem and root rot in both chrysanthemums for cut flowers and in hydroponically grown potted chrysanthemums produced in an ebb and flow mat irrigation system in Japan. Since

reduction in yields and plant death can occur, *P. chrysanthemi* is a pathogen of concern. However, the infrequent detections from geographically dispersed locations suggest that this pathogen may be a minor pest needing specific conditions for disease development that are not well defined and that occur infrequently.

Potential pathways of introduction: Since many *Phytophthora* spp. are reported to move in plant material, such as nursery stock (Bulluck et al., 2006; Tubajika et al., 2006), it is likely that this pathogen may have entered in propagative material. Currently, *Chrysanthemum* spp. plants for planting are prohibited entry into the United States from many countries, including Croatia and Japan, due to the presence of chrysanthemum white rust (*Puccinia horiana*) and are allowed only under special permits. (7 CFR 319.37-5(c); USDA-APHIS-PPQ, 2014). This also applies to cut chrysanthemums intended for propagation. If use is not noted for cut chrysanthemums, then use is assumed to be for propagation (USDA-APHIS-PPQ, 2014). These requirements lower the risk of movement of other plant pathogens in chrysanthemum cut flowers and plants for planting.

The pathway for introduction and the origin of *P. chrysanthemi* are unknown for the United States. It is hypothesized in two papers that *P. chrysanthemi* is indigenous, either living as a saprophyte in the natural environment and growing and spreading well when introduced into hydroponic culture systems (Naher et al., 2011), or limited to some areas and not previously detected because of similarity of symptoms with *Pythium*, *Rhizoctonia*, and *Fusarium* species (Tomic and Ivic, 2015). It was also hypothesized that *P. chrysanthemi* only recently became pathogenic to chrysanthemums (Tomic and Ivic, 2015). Evidence on saprophytic capability (ability to live as a saprophyte) is also lacking for *P. chrysanthemi*; however, *Phytophthora* species do not survive well as saprophytes (Erwin and Ribeiro, 1996). Although the likelihood is low that this pathogen fairs well as a saprophyte, it may still be endemic to Japan. Naher et al. (2011) postulated that the pathogen may have arrived to Japan in imported peat moss, but without more information on the capability of survival structures, this postulation is unsupported. No link has been found between the any of these detections (Tomic and Ivic, 2015), further supporting the statement than the pathway for introduction and point of origin for *P. chrysanthemi* are unknown.

Potential distribution in the United States and spread: This pathogen is tolerant of high temperatures (Yang et al., 2014) and is associated only with *Chrysanthemum* spp. It has been detected in chrysanthemums planted in the soil in plastic-covered production systems (Croatia), in greenhouse production for cut flowers (Japan), and in hydroponic systems (Japan) (Naher et al., 2011). Areas reported in distribution section (Naher et al., 2011; Tomic and Ivic, 2015; Bowers, 2016) collectively correspond to U.S. Plant Hardiness Zones of 6-10. However, chrysanthemums can be produced in greenhouses, and since *P. chrysanthemi* culture prefers warmer temperatures in culture (Naher et al., 2011), it would be expected to grow well in greenhouses across the United States.

Like other *Phytophthora* spp., *P. chrysanthemi* may move in soil, water, and plant material (Erwin and Ribeiro, 1996). Humans may assist in this movement through irrigation, movement of soil on farming equipment, movement by contaminated tools, and movement of infected plant material as they do with other *Phytophthora* species. However, the uncertainty is high with this pathogen, since no origin source or pathway has been identified, only hypothesized (Tomic and Ivic, 2015; Naher et al., 2011).

Detection: Symptoms of *P. chrysanthemi* infection allow for visual detection, as noted in the detections in Croatia and Japan. However, visual inspection does not allow for differentiation among species of *Phytophthora* or from other pathogens such as *Pythium* spp., *Fusarium* spp., *Rhizoctonia* spp., and other *Phytophthora* spp. that incite similar symptoms (Tomic and Ivic, 2015). Several *Phytophthora* species have been reported infecting chrysanthemums in the world, but only three were noted to occur on chrysanthemum in the United States: *Phytophthora cryptogea*, *P. nicotianae* (*P. parasitica*), and *Phytophthora* sp. (Farr and Rossman, 2016). Some of these species reported, such as *P. cryptogea* and *P. nicotianae*, cause symptoms similar to those reported for *P. chrysanthemi* (stem and root rot, death, etc.) (Erwin and Ribeiro, 1996; Tomic and Ivic, 2015), whereas other species incite

a different complement of symptoms, such as *P. cactorum*, which causes blighting as well as stem rot (Naher et al., 2011).

Phytophthora chrysanthemi can be differentiated from other *Phytophthora* species by how it grows on specified media. It must first, however, be isolated, which is best done with a selective medium (PARP) (Tomic and Ivic, 2015). In Croatia, the pathogen was successfully baited from soil with chrysanthemum leaves (Tomic and Ivic, 2015). *Phytophthora chrysanthemi*'s growth on media is "characterized by nonpapillate, noncaducous sporangia with internal proliferation, formation of both hyphal swellings and chlamydospores, homothallic nature, distinctive intercalary antheridia, and funnel-shaped oogonia" (Naher et al., 2011). *Phytophthora cactorum* and *P. chrysanthemi,* in addition to having a difference in symptoms, also have different optimum growth temperatures, 25 °C for *P. cactorum* and 30 °C for *P. chrysanthemi.* In Japan, the two pathogens induce symptoms in different times: May, June, September, and October for *P. cactorum* and July and August for *P. chrysanthemi (*Naher et al., 2011). "There is no report of chrysanthemum diseases caused by *Phytophthora* species at high temperatures in chrysanthemums grown hydroponically in ebb and flow irrigation systems" (Naher et al., 2011).

Molecular methods are the best are differentiating *Phytophthora* species from other pathogens and from each other. Molecular methods are available, including commercially available lateral flow devices that identify pathogens to the genus level. Methods use to confirm the recent detection in the United States were conventional PCR and BLAST analysis of DNA sequences from seven molecular markers: Beta-Tubulin (BT), Cytochrome c Oxidase (COI), Heat Shock Protein 90 (HS), Internal Transcribed Spacer rDNA (ITS rDNA), 60S ribosomal protein L10 (L10), translation elongation factor (EF), and ras-like related ypt1 protein (Ypt1) (Bullington, 2016).

Control: Tomic and Ivic (2015) included the following as essential measures to combat *P. chrysanthemi:* use pathogen free seedlings and cuttings; use sanitation measures to prevent the infection of these plant parts; use clean water and avoid heavy moisture levels in the potting medium or soil; water the roots of seedlings with registered fungicides; and disinfect the soil and potting medium. It is possible that *P. chrysanthemi* intensively occurs in greenhouses when floors are not disinfected (Tomic and Ivic, 2015). Many management options are available for other *Phytophthora* species in the United States (Erwin and Ribeiro, 1996), including those measures recommended by Tomic and Ivic (2015). Searching for extension recommendations for control of *Phytophthora* spp. on *Chrysanthemum* yielded limited results, suggesting that *Phytophthora* diseases are not common problems on *Chrysanthemum* in the United States. *Pythium* species, closely related to *Phytophthora* species, do have recommended control measures. Control for *Pythium* root and stem rot includes planting in pasteurized soil or soilless mix free of the pathogen and applying fungicides to protect healthy plants (Penn State, 2016).

Potential economic impacts: Infection by *Phytophthora chrysanthemi* can result in small, unmarketable plants and plant death, reducing both cut flower and potted plant yields (Naher et al., 2011; Tomic and Ivic, 2015). *Phytophthora chrysanthemi* can kill *Chrysanthemum* plants (Tomic and Ivic, 2015).

Chrysanthemums are sold as cut flowers, potted florists mums, and garden mums, and are valuable in the floriculture industry. The following quantities and values of the three chrysanthemum products are averaged for 2013 and 2014 (NASS, 2015).

- Chrysanthemum cut flowers: 7.9 million bunches valued at $12.6 million
- Potted florist mums: 28.16 million plants valued at $72.3 million
- Potted hardy/garden mums: 48.2 million plants valued at $115 million

U.S. global exports of chrysanthemum plants between January 2011 and December 2015 ranged between 2,000 and 18,100 plants annually (FAS, 2016). Countries receiving these exports were Brazil, Sweden, the Bahamas, Chile, Cayman Islands, Germany, Guatemala, Mexico, Panama, and the United Kingdom; however, none of the countries received these exports for more than three years of this five-year period (FAS, 2016). Most chrysanthemum cut flowers exported from the United States go to Canada, with exports to Haiti ($3,000 in 2012) and Mexico ($46,000 in 2011) each occurring only in one year. The annual value ranged between $1,269,000 and $3,204,000 in the period between 2011 and 2015 (FAS, 2016).

Since this pathogen has been detected in only a few locations globally, and since there are management options for related pathogens available in the United States, the potential impact most likely will be well below the economic loss associated with the only reported disease incidence of 15 percent. The need to replant the damaged plants for MumFest is evidence of a potential economic impact on tourism. No known indirect impacts on human or animal health were found.

Trade implications: The pathogen has now been reported on three continents, but apparently is only present in very small areas on each continent. No countries currently regulate *P. chrysanthemi* (PExD, 2016; queried 2/23/2016). Countries have restrictions for various *Chrysanthemum* plant parts for other reasons: for example, cuttings are restricted by Australia, Bangladesh, Chile, Guatemala, Japan, Mexico, Nauru, and Tunisia; plantlets are restricted by Bangladesh, the Russian Federation, and Tunisia; stems are restricted by Bangladesh and Taiwan; and host plants are restricted by over 40 countries (PExD, 2016; queried 2/23/2016). The impact of this pathogen is unknown and a bit difficult to predict: it is a newly described species, no countries currently regulate it, there is uncertainty as to its full geographic distribution, the point of origin is unknown. However, it should be noted that the original isolates were detected in 1998 (Naher et al., 2011), and since that time there have been limited detections of this pathogen (Naher et al., 2011; Tomic and Ivic, 2015; Bowers, 2016).

Potential environmental impacts: No species of *Chrysanthemum* are listed as threatened or endangered in the United States. Only a few species are naturalized in the United States, and only one, *Chrysanthemum articum*, is native, in Alaska and both native and introduced in New York and Connecticut (USDA NRCS, 2016). Based on potential spread and growth rates in culture at different temperatures, this pathogen would not be expected to grow at the lower temperatures encountered in Alaska or most of New York, except in greenhouse production. There is uncertainty, however, because the survival capabilities of the oogonia and chlamydospores of *P. chrysanthemi* are unknown.

Uncertainty: The known distribution of *Phytophthora chrysanthemi* is very limited, but considering the difficulty of isolating this pathogen in the past and the overlap in symptomatology with other pathogens, the distribution is likely greater than reported in the current literature. The few reports of this pest all suggest that the host range of this pathogen is limited to one genus. This pathogen does cause plant decline and death in *Chrysanthemum*, but there is only one report of disease incidence, and few reports of management options for *Phytophthora* spp. on *Chrysanthemum* were found in U.S. extension literature, all of which highlight the uncertainty association with potential impact by this pathogen. Both pathways for movement and survival capabilities are unknown.

Need for new technology or knowledge:

- Determine the distribution of this pathogen globally. This pathogen has occurred in damaged host material with symptoms similar to *Pythium*, *Rhizoctonia*, and *Fusarium* infections and can be difficult to isolate without a selective medium.
- Determine the pathway of introduction into the United States.
- Survival capabilities of oogonia and chlamydospores, the survival structures of other *Phytophthora* spp., are untested for *P. chrysanthemi*.

National Plant Board consultation: None.

References:

Erwin, D. C., and O. K. Ribeiro. 1996. Phytophthora Diseases Worldwide. APS Press, St. Paul, MN. 562 pp.

Farr, D. F., and A. Y. Rossman. 2016. Fungal Databases - *Phytophthora chrysamthemi*. Systematic Botany and Mycology Laboratory, ARS, USDA. Last accessed March 22, 2016, http://nt.ars-grin.gov/fungaldatabases/index.cfm.

FAS. 2016. Global Agricultural Trade System (GATS) Online. United States Department of Agriculture, Foreign Agricultural Service (FAS). http://www.fas.usda.gov/ustrade/. (Archived at PERAL).

GenBank. 2016. Search for *Phytophthora chrysanthemi* accessions. National Library of Medicine. http://www.dtd.nlm.nih.gov/genbank/. (Archived at PERAL).

Jung, T., L. B. Orlikowski, B. Henricot, P. Abad-Campos, A. G. Aday, O. Aguin Casal, J. Bakonyi, S. O. Cacciola, T. Cech, D. Chavarriaga, T. Corcobado, A. Caravador, T. Decourcelle, G. Denton, S. Diamandis, H. T. Dogmus-Lehtijarvi, A. Franceschini, B. Ginetti, M. Glavendeki, S. Green, J. Hantula, G. Hartmann, M. Herrero, D. Ivic, M. H. Jung, A. Lilja1, N. Keca1, V. Kramarets, A. Lyubenova, H. Machado, G. M. d. S. Lio, P. J. M. Vazquez, B. Marcais, I. Matsiakh, I. Milenkovic, S. Moricca1, Z. A. Nagy, J. Nechwatal, C. Olsson, T. Oszako, A. Pane, E. J. Paplomatas, C. P. Varela, S. Prospero, C. R. Martınez, D. Rigling, C. Robin, A. Rytk€one, M. E. Sanchez, B. Scanu, A. Schlenzig, J. Schumacher, S. Slavov, A. Solla, E. Sousa, J. Stenlid, V. Talgø, Z. Tomic, P. Tsopelas, A. Vannini, A. M. Vettraino, M. Wenneker, S. Woodward, and A. Perez-Sierra. 2015. Widespread *Phytophthora* infestations in European nurseries put forest, semi-natural and horticultural ecosystems at high risk of Phytophthora diseases. Forest Pathology, Published online: DOI: 10.1111/efp.12239.

Naher, M., K. Motohash, H. Watanabe, Y. Chikuo, M. Senda, H. Suga, C. Brasier, and K. Kageyama. 2011. *Phytophthora chrysanthemi* sp. nov., a new species causing root rot of chrysanthemum in Japan. Mycological Progress 10:21-31.

NASS. 2015. Floriculture Crops 2014 Summary (June 2015). United States Department of Agriculture, National Agricultural Statistics Service (NASS).

Penn State. 2016. Chrysanthemum Diseases. Pennsylvania State University, Penn State Cooperative Extension. www.extension.psu.edu.

PestID. 2016. Pest Identification Database (PestID). United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine. https://mokcs14.aphis.usda.gov/aqas/login.jsp (Archived at PERAL).

PExD. 2016. Phytosanitary Export Database (PExD). United States Department of Agriculture. (Archived at PERAL).

Tomic, Z. 2016. FW: *Phytophthora chrysanthemi*. Personal communication to B. Randall-Schadel on February 23, 2016, from Zeljko Tomic, Head of Laboratory for Mycology, Croatian Centre for Agriculture, Food and Rural Affairs, Institute for Plant Protection, Zagreb, Croatia.

Tomic, Z., and D. Ivic. 2015. *Phytophthora chrysanthemi* Naher, Motohash, Watanabe, Chikuo, Senda, Suga, Brasier & Kageyama - new cause of chrysanthemum disease in Croatia. Glasilo biljne zaštite 15(4):291-300.

Tubajika, K. M., R. Bulluck, P. J. Shiel, S. E. Scott, and A. J. Sawyer. 2006. The occurrence of *Phytophthora ramorum* in nursery stock in California, Oregon, and Washington states. Online. Plant Health Progress:doi:10.1094/PHP-2006-0315-1002-RS.

USDA-APHIS-PPQ. 2014. Cut Flowers and Greenery Import Manual. Plant Protection and Quarantine (PPQ), Animal and Plant Health Inspection Service (APHIS), U.S. Department of Agriculture (USDA), Washington, D.C. 156 pp.

USDA NRCS. 2016. The PLANTS Database, Version 3.5. National Plant Data Center, National Resources Conservation Service (NRCS), U.S. Department of Agriculture (USDA), Baton Rouge, LA. Last accessed March 2, 2016, http://plants.usda.gov.

Yang, X., M. E. Gallegly, and C. X. Hong. 2014. A high-temperature tolerant species in clade 9 of the genus Phytophthora: P-hydrogena sp nov. Mycologia 106(1):57-65.

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