Ceratocystis manginecans (van Wyk et al., 2007)

Synonyms
Ceratocystis acaciivora M. Tarigan & M. van Wyk (Fourie et al. 2015)

Common Name(s)
Sudden mango decline

Type of Pest
Fungus

Taxonomic Position
Class: Sordariomycetes, **Order:** Microascales **Family:** Ceratocystidaceae

Reason for Inclusion in Manual
National Threat

Background Information
Sudden mango decline was first noted in mango during 1998 in the Barka area in southern Oman (Al Adawi et al., 2003). This disease is now known to be caused by the virulent fungal pathogen, *Ceratocystis manginecans* (Al Adawi et al., 2006; van Wyk et al., 2007). When sudden mango decline was first discovered, the cause was initially attributed to various factors, including heavy infestations of bark beetles. Bark beetles collected from diseased mango trees were identified as *Hypocryphalus mangiferae* (Fig. 3), which is now known to vector *C. manginecans* (Al Adawi et al., 2013a).

Sudden mango decline caused by *C. manginecans* is very similar to a mango disease in Brazil known as seca. Seca is caused by other *Ceratocystis* spp. and is also vectored by *H. mangiferae* (van Wyk et al., 2011; Ploetz et al., 2013). *Ceratocystis manginecans*, however, is not known to be present in the western hemisphere (Ploetz et al., 2013). The original host(s) and geographic origin for *C. manginecans* are unclear, but there is emerging evidence that it is an Asian fungus (Ploetz et al., 2013).

Ceratocystis manginecans is a member of the *C. fimbriata sensu lato* species complex, which is an assemblage of morphologically similar and phylogenetically closely related species. In this complex, *C. manginecans* is most closely related to *C. cacaofunesta* (Tarigan et al., 2011). *Ceratocystis manginecans* was previously thought to be most closely related to *C. acaciivora*, which is responsible for a debilitating canker and wilt disease of plantation-grown *Acacia mangium* in Indonesia (Tarigan et al., 2011). However, *C. manginecans* and *C. acaciivora* were reduced to synonymy based on DNA analysis (Fourie et al., 2015).

Figure 1. Wilting and death of all or portions of mango trees infected with *C. manginicans* in Oman. Photo courtesy of Randy Ploetz.

Pest Description

From van Wyk et al., (2007):

Ceratocystis* teleomorph:* Grayish olive in color on 2% Malt Extract Agar (MEA). *Odor* banana. *Hyphae* smooth and segmented. *Ascomatal bases* globose, black, (153-) 192-254(-281) µm in diameter. *Ascomatal necks* dark brown becoming lighter towards apices (514-) 557-635(-673) µm long, (25-)32 42(-48) µm wide at base, (14-) 16-22(-26) µm wide at tip. *Ostiolar hyphae* hyaline, divergent, (42-)45-59(-69) µm long. *Asci* evanescent, not seen. *Ascospores* hyaline, hat shaped, 3-4 µm in length, 4-5 µm wide excluding sheath, 7-8 µm wide including sheath. **For microscopic images of *C. manginecans*, see van Wyk et al. (2007).**

***Thielaviopsis*-like anamorph:** *Conidiophores* of two morphological forms. Primary conidiophores phialidic, lageniform, hyaline, (72-)81-109(-144) µm long, 5-7(-9) µm wide at bases, 6-8(9) µm wide at broadest point, 3-6 µm wide at tips. *Secondary conidiophores*, tube-like, flaring at mouths, short, hyaline, (59-)65-77(-84) µm long, 5-8 µm wide at bases and (5)6 8 µm wide at tips. *Conidia* of two types. *Primary conidia*, hyaline, cylindrical, (15-)23-29(33) µm in length, 3-6 µm wide. *Secondary conidia*, hyaline, barrel-shaped, (8-)9-11(-12) µm in length, 5-7(-8) µm wide. *Chlamydospores* brown, thick-walled, globose to sub-globose, (11-)12-14 µm in length by 9-11(-12) µm wide.

Figure 2. (a) External evidence for boring activity of the bark beetle vector of *C. manginecans*, *Hypocryphalus mangiferae*; and (b) necrosis of the cambium (left) in which galleries of *H. mangiferae* are evident (center). Photos courtesy of Randy Ploetz.

Biology and Ecology

Isolates of *C. manginecans* from Oman and Pakistan, respectively, displayed similar growth patterns in culture and grew optimally between 20-25°C (68-77°F). No growth was observed at 5°C (40°F), 10°C (50°F) and 35°C (96°F). After 7 days, both cultures reached an average of 27 mm and 29 mm at 15°C (59°F) and 30°C (86°F), respectively. At 20°C (68°F) both isolates had reached an average of 43 mm and at 25°C (77°F) an average diameter of 45 mm was reached (van Wyk et al., 2007).

Affected mango trees have wilting symptoms that usually begin on one side and later spread to involve the entire tree (Fig. 1) (Al Adawi et al., 2003). Examination of mango trees suffering from sudden decline revealed that symptoms of the disease begin on healthy trees at the sites of *H. mangiferae* entrance holes (Fig. 2a). Colonization by *H. mangiferae* (Fig. 3) is mainly initiated towards the bases of mango trees where the stems were thickest. Longitudinal cuts into infested stems revealed that beetle tunnels were restricted to the bark, did not extend into the xylem, were short, and in only one

Figure 3. *Hypocryphalus mangiferae*, the vector of *C. manginecans*. Length is approximately 1.6-1.9mm. Photo credit: J.E. Mercado, *Bark Beetle Genera of the United States* (CSU, USDA-APHIS-PPQ-CPHST, and USDA-FS-RMRS).

instance, contained eggs (Al Adawi et al., 2013a). Bark beetle infestation is followed, in most cases, by the exudation of gum at the sites where insects enter the stems. Brown to black vascular discoloration develops in wilted and severely affected trees (Al Adawi et al., 2006). Once external symptoms become apparent, *C. manginecans* can readily be isolated from discolored woody tissues (Al Adawi et al., 2013a).

The manner in which *H. mangiferae* disseminates *C. manginecans* is currently unknown. Further study is needed to determine how *C. manginecans* is associated with *H. mangiferae* (Al Adawi et al., 2013a).

Symptoms/Signs

Sudden mango decline is characterized by gummosis (a pathologic condition characterized by excessive formation of gums; the products of cell degeneration) from the bark of infected trees, vascular discoloration of the woody tissues and wilt symptoms on one side of the tree followed by death of the entire tree (Fig. 1), which usually occurs within 6 months of first appearance of symptoms (Al-Adawi et al. 2006). Inoculation of mango seedlings with *C. manginecans* resulted in the production of wilt symptoms, gummosis, and necrosis/discoloration of the vascular system (Fig. 2b). The thin sections of the infected mango stems, but not those of control seedlings, showed darkening of tissues. Mycelium of *C. manginecans* was also detected in the vascular system of the inoculated mango seedlings. In addition, tyloses were detected in the xylem vessels of infected tissues but were absent from the non-inoculated tissues. Diseased trees always showed signs of damage caused by the bark beetle *H. mangiferae* (Fig. 2a) (Al Sadi et al., 2010).

In Oman, the majority of diseased trees developed large, inconspicuous trunk cankers where the bark appeared darker than normal. Beneath the affected bark underlying

tissues were discolored brown to black (Fig. 2b). Rootstocks of grafted trees frequently were severely affected compared with the scion, which was commonly asymptomatic. Cankers located near ground level often resulted in death of the entire tree, especially with grafted trees. However, local varieties in Oman appeared to be more severely affected than exotic scions on grafted trees (Al Adawi et al., 2006).

Pest Importance

Since 1998, mango production in Oman has been devastated by sudden mango decline disease. Over 60,000 trees have been killed or removed due to the disease since its first occurrence in the country. Mango production in Oman decreased by 43% from 1997-2007, with virtually all of this decrease attributed to *C. manginecans* (Al Sadi et al., 2010).

Mango is an important crop in Puerto Rico. In 2012, mango was grown in Puerto Rico on 157 farms, and 167,130 trees of bearing age were present on the island (USDA, 2012a).

Mango-bearing and non-bearing acreage in the continental United States as of 2012 was 3,006 acres, all in California, Florida, Hawaii, and Texas. The majority of this acreage is located in Florida (USDA-NASS, 2014).

At the genus level, *Ceratocystis* spp. is listed as a harmful organism in Namibia and South Africa (PExD, 2015). There may be trade implications with these two countries if *C. manginecans* becomes established in the United States.

Known Hosts

Major hosts:

Mangifera indica (mango) (van Wyk et al., 2007).

Other hosts:

Acacia spp. (acacia, wattles), *Acacia crassicarpa* (northern wattle), *Acacia mangium* (brown salwood), *Dalbergia sissoo* (Shisham), and *Prosopis cineraria* (Ghaf) (Tarigan et al., 2011; Al Adawi et al., 2013b; Ploetz et al., 2013).

Known Vectors (or associated insects)

Hypocryphalus mangiferae (mango bark beetle) is a confirmed vector of *C. manginecans* to mango (Al Adawi et al., 2013a). It is likely that wood boring insects vector *C. manginecans* to other hosts, but no other vector has been identified (Tarigan et al., 2011; Al Adawi et al., 2013b).

Known Distribution

Asia: Indonesia, Malaysia, Oman, Pakistan, and Vietnam (van Wyk et al., 2007; Tarigan et al., 2011; Ploetz et al., 2013).

Pathway

There have been shipments of *Mangifera* spp. plant material from Indonesia (2) and Vietnam (1) to Hawaii since 2005. These shipments contained a combined total of 35 Plant Units (AQAS, 2015). There have also been shipments of *Mangifera* spp. plant material from Vietnam (1) and Pakistan (1) to California since 2005 (AQAS, 2015). Import of mango seed material is allowed into Hawaii, Guam, and the Mariana Islands (USDA, 2015), although it is unknown if this fungus is seed transmitted.

Since 2005, there have also been interceptions of *Mangifera* spp. from Pakistan at ports of entry in California (25) and Florida (2). While most of these interceptions consisted of fruit intended for consumption, one interception in California was plant material intended for propagation. There have also been interceptions of *Mangifera* spp. fruit intended for consumption from Indonesia at ports of entry in California (11), Texas (5), and Florida (1) (AQAS, 2015).

Currently, the import of mango fruit is allowed from Pakistan (FAVIR, 2014). However, there have been no shipments from this country to any U.S. port of entry since 2005 (AQAS, 2015).

Potential Distribution within the United States

Mango is grown commercially in Puerto Rico, Hawaii, Florida, California, and Texas (USDA, 2012a; USDA-NASS, 2014). *Acacia* spp. are present in California, Florida, Arizona, and Oregon. *Dalbergia sissoo* is also present in Arizona and Florida (BONAP, 2014).

Hypocryphalus mangiferae is present in Florida (Atkinson and Peck, 1994). The vectors is also reported to occur in Puerto Rico (Cabrera-Asencio,1996; Bright and Torres, 2006; CABI, 2013). If *C. manginecans* were found in Florida or Puerto Rico, it would likely be spread by this bark beetle vector wherever mango is grown in the state/territory.

Survey

Approved Method for Pest Surveillance:

The CAPS-approved survey method is to collect symptomatic plant tissue by visual survey.

Visual symptoms of *C. manginecans* infection are well described (van Wyk et al., 2007; Ploetz et al., 2013; Al Adawi et al., 2013a). Visual symptoms in infected mango hosts include: Wilting of the crown, entrance holes of *H. mangifera*, stem lesions showing vascular discoloration, and gum exuding from bark of an infected stem (van Wyk et al., 2007).

*For the most up-to-date methods for survey and identification, see Approved Methods on the CAPS Resource and Collaboration Site, at https://caps.ceris.purdue.edu/approved-methods.

Key Diagnostics

Approved Method for Pest Surveillance:

The approved diagnostic method is morphological identification. Morphological characteristics of *C. manginecans* are described in van Wyk et al. (2007).

Ceratocystis manginecans can easily be distinguished from *C. fimbriata sensu stricto* by the production of both secondary and primary conidiophores and both cylindrical and barrel-shaped conidia, respectively. *Ceratocystis fimbriata sensu stricto* does not produce secondary conidiophores that produce barrel-shaped conidia (van Wyk et al., 2007).

*For the most up-to-date methods for survey and identification, see Approved Methods on the CAPS Resource and Collaboration Site, at https://caps.ceris.purdue.edu/approved-methods.

Literature-Based Methods:

For molecular identification, comparisons of DNA sequence data for the Internal Transcribed Spacer (ITS), β-tubulin, and Transcription Elongation Factor (TEF) 1-α gene regions of *C. manginecans* were used (van Wyk et al., 2007; Tarigan et al., 2011). These comparisons confirmed previous findings based on morphological characteristics (van Wyk et al., 2007).

Rashid et al. (2013) sequenced and analyzed the nuclear encoded ITS1-5.8s –ITS2 rDNA region of *C. manginecans.* This study of ITS sequences distinguished *C. manginecans* from other *Ceratocystis* spp., and it also identified differences in sequences of *C. manginecans* isolates from Pakistan from *C. manginecans* isolates from other countries.

The genome of *C. manginecans* has recently been published (van der Nest et al., 2014). This will provide more insight on this pathogen in the future.

Easily Confused Species

A very similar wilt disease of mango, seca, has been known in Brazil since 1938. The bark beetle *H. mangiferae* is also a significant factor in the development of seca (Ploetz, 2003). Several *Ceratocystis* spp. strains are associated with seca, and they are collectively referred to as the *Ceratocystis fimbriata sensu lato* species complex (van Wyk et al., 2007). Van Wyk et al. (2011) described two new species with multigene geneologies, *Ceratocystis mangicola* and *C. mangivora*, in a collection of seca isolates from Brazil and identified them as distinct species. *Ceratocystis manginecans* is closely related to but distinct from *C. mangicola* and *C. mangivora* (van Wyk et al., 2011; Ploetz et al., 2013).

The *C. manginecans* isolates from Pakistan and Oman are morphologically similar to *C. platani* (van Wyk et al., 2007), but *C. platani* does not affect any known host of *C. manginecans.*

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