ASSOCIATION OF BOTRYOSPHAERIACEAE AND PHAEACREMONIUM SPECIES WITH INSECT-DAMAGED QUINCE SHOOTS

H. Mohammadi and S. Sharifi

Department of Plant Protection, Faculty of Agriculture, Shahid Bahonar University of Kerman, Kerman, 7616914111, Iran

SUMMARY

During a study of fungal flora associated with fruit trees decline in Lorestan province (Iran), 54 isolates of Phaeoacremonium and Botryosphaeriaceae were obtained from symptomatic wood, borer holes, larvae of the beetles associated with the insect-damaged shoots and adult of beetles around the affected quince (Cydonia oblonga) trees showing leaf chlorosis, canker, dieback or decline symptoms. Based on morphological and molecular studies isolates were identified as Diplodia seriata, Dothiorella sarmentorum, Lasiodiplodia theobromae, Phaeoacremonium alvesii, P. mortoniae, P. parasiticum and P. viticola. Phaeoacremonium parasiticum, the most common species, was successfully isolated from discolored woody tissues, borer holes and larvae of the beetles, while P. viticola was obtained from discolored woody tissues, borer holes and larvae, but not from adult beetles. Phaeoacremonium alvesii and P. mortoniae were only isolated from discolored woody tissues and borer holes, respectively. Dothiorella sarmentorum was obtained from discolored tissues, borer holes and adult beetles and D. seriata and L. theobromae were obtained from borer holes and discolored tissues. A pathogenicity test was conducted on detached shoots of quince with 1-5 isolates for each species. Lasiodiplodia theobromae produced significantly longer lesions than the other species, whereas D. seriata caused the smallest lesions 35 days after inoculation. This study represents the first report on occurrence and pathogenicity of Phaeoacremonium and Botryosphaeriaceae species associated with insect-damaged shoots in quince trees, which 28 species have been found on grapevine worldwide (Crous et al., 1996; Dupont et al., 2000; Groenewald et al., 2001; Mostert et al., 2005, 2006; Damm et al., 2008; Essakhi et al., 2008; Graham et al., 2009; Gramaje et al., 2009, 2012, 2014; Raimondo et al., 2014; Úrbez-Torres et al., 2014). Species of Phaeoacremonium are known to be the main pathogens associated with two destructive grapevine decline diseases, i.e. esca and Petri disease (Mostert et al., 2006). Although most of Phaeoacremonium spp. have been reported from grapevine, numerous species of these taxa have also been identified from other woody plants such as pome fruit trees (Cloete et al., 2011; Sami et al., 2014), Prunus spp. (Damm et al., 2008; Gramaje et al., 2012), date palm (Mohammadi, 2014), ornamental trees (Mostert et al., 2006; Mohammadi et al., 2014), kiwifruit (Prodi et al., 2008), olive (Carlucci et al., 2015) and sandalwood

INTRODUCTION

Quince (Cydonia oblonga Mill) is native to western Asia and believed to be originated from Northern Iran, Turkmenistan, and the far west regions of Anatolia and Greece (Sykes, 1972; Richard and Leitão, 2011). Quince is the third most important pome fruit produced (after apple and pear) in Iran, covering an area of 5,000 ha from which 36,500 metric tons are harvested every year. In 2012, Iran was the fifth quince producer after Turkey (135,406 tons), China (125,000 tons), Uzbekistan (80,000 tons) and Morocco (46,000 tons) (FAO, 2012). In Iran, the main quince orchards are established in Isfahan, Khorassan Razavi, Fras, Kerman, Semnan, Zanjan and Lorestan provinces. In June 2012, a severe decline of quince trees was observed in some orchards in Lorestan (Western Iran) province. Disease symptoms included leaf chlorosis, canker and dieback. Cross sections of affected branches showed insect damage (borer holes) as well as discoloration in woody tissues similar to grapevine trunk diseases (Mohammadi and Banihashemi, 2012; Mohammadi et al., 2013; Van Niekerk et al., 2011).

Numerous fungal taxa are known to cause trunk diseases of woody plants worldwide. Extensive studies have been conducted on Phaeoacremonium and Botryosphaeriaceae species because of the involvement of these pathogens in grapevine trunk diseases. The anamorph genus Phaeoacremonium W. Gams, Crous & M. Wingf. was originally described by Crous et al. (1996). Since 1996 a total of 46 species of this genus have been identified, of which 28 species have been found on grapevine worldwide (Crous et al., 1996; Dupont et al., 2000; Groenewald et al., 2001; Mostert et al., 2005, 2006; Damm et al., 2008; Essakhi et al., 2008; Graham et al., 2009; Gramaje et al., 2009, 2012, 2014; Raimondo et al., 2014; Úrbez-Torres et al., 2014). Species of Phaeoacremonium are known to be the main pathogens associated with two destructive grapevine decline diseases, i.e. esca and Petri disease (Mostert et al., 2006). Although most of Phaeoacremonium spp. have been reported from grapevine, numerous species of these taxa have also been identified from other woody plants such as pome fruit trees (Cloete et al., 2011; Sami et al., 2014), Prunus spp. (Damm et al., 2008; Gramaje et al., 2012), date palm (Mohammadi, 2014), ornamental trees (Mostert et al., 2006; Mohammadi et al., 2014), kiwifruit (Prodi et al., 2008), olive (Carlucci et al., 2015) and sandalwood...
Species of *Botryosphaeriaceae* live as endophytes with a latent phase that can cause important diseases in plant hosts around the world. Many members of this family are significant plant pathogens causing cancer, leaf blight, fruit rots, blight of shoots, gummyosis, dieback and wood discoloration (Slippers et al., 2007; Slippers and Wingfield, 2007). These pathogens have been associated with mortality processes of economically important woody plants such as pome and stone fruit trees (Slippers et al., 2007; Cloete et al., 2011; Sami et al., 2014), forest trees (Burgess et al., 2005; Azouaouidi-Idjer et al., 2012; Alves et al., 2013; Mehl et al., 2014), grapevines (Qiu et al., 2011; Spagnolo et al., 2011; Úrbez-Torres et al., 2010, 2012), olive (Lazzizera et al., 2008), mango (Israil et al., 2001), almond (Inderbitzin et al., 2010) and walnut (Chen et al., 2014).

Some species of *Phaeoacremonium* and *Botryosphaeriaeaceae* have also been obtained from insect larvae and adults (Kubátová et al., 2004; Epstein et al., 2008; Moyo, 2013). Insects have been suspected to play a role in the dissemination of these pathogens (Rooney-Latham et al., 2005; Epstein et al., 2008; Moyo, 2013). It is thus assumed that insects that come into contact with spores of trunk disease pathogens can potentially act as dispersal agents. However, further studies are needed to evaluate whether insects can vector *Phaeoacremonium* and *Botryosphaeriaeaceae* species to healthy plants. Association of some arthropods with reproductive propagules of the main fungal trunk pathogens such as *Phaeomoniella clamydiospora* [formerly= *Phaeoacremonium clamydiosporum*] (W. Gams, Crous and M.J. Wingf. and L. Mugnai) Crous & W. Gams) [Edwards et al., 2001], *Phaeoacremonium* spp. (Kubátová et al., 2004; Moyo, 2013), some species of *Botryosphaeriaeaceae* (Epstein et al., 2008; Moyo, 2013), Diatrypaceae and Diaporthales (Moyo, 2013) have been reported. In Iran, few studies have been conducted on trunk diseases of pome fruit trees (Arzanlou et al., 2014; Sami et al., 2014) and the causal agents in many cases are still unknown. Therefore the objective of this study was to identify fungal species associated with insect-damaged quince branches in Lorestan province. An attempt was also made to isolate fungi from larvae insects in woody tissues of symptomatic plants and rove adult beetles in quince orchards.

**MATERIALS AND METHODS**

**Sampling.** Eleven quince orchards located in Lorestan province showing decline and insect damage symptoms were examined between 2012 and 2013. Samples were collected from woody branches of trees (showing leaf chlorosis, canker, dieback or decline symptoms), larvae of beetles associated with wood damage (borer holes) as well as rove beetles in orchards. Woody samples were visually inspected for different kinds of internal wood discoloration and insect damage. Fungal isolations were carried out from the different zones of discolored and damaged tissues. Small woody fragments (3 × 3 mm) between discolored and healthy tissues were surface-sterilized in a bleach solution (0.5% active chlorine) for 1.5 min and washed with sterile distilled water. Wood pieces were plated on Petri dishes containing malt extract agar (MEA) supplemented with 100 mg l⁻¹ streptomycin sulphate (MEAS). Plates were incubated at 25°C for several days in the dark. The microorganisms that developed were subsequently transferred to fresh medium and incubated at 25°C. Fungal isolation was also attempted from the larvae borer into the wood of the affected trees and adults of beetles collected from orchards. Collected larvae and beetles were separately placed into sterile tubes filled with 10-15 ml sterile water. Tubes were shaken for 30 seconds to loosen any fungal spores present on their bodies and exoskeletons (Roets et al., 2006). One milliliter of the water was transferred onto MEA and spread evenly with a sterile L-shaped rod. Plates were incubated at 25°C and germinated spores were subsequently transferred to fresh medium in order to obtain pure cultures for further species identification.

**Morphological and molecular identification.** The initial identification of isolates was made based on morphological and cultural characteristics. *Phaeoacremonium* isolates were identified by colony and microscopic structures according to Mostert et al. (2006). Microscopic characters to distinguish species of *Phaeoacremonium* included conidiophore morphology, conidial size and shape, phialide type and shape, and size of hyphal warts. The presumptive morphological identifications of *Phaeoacremonium* species were confirmed by analysis of partial β-tubulin gene sequences amplified using the primer sets T1 (O’Donnell and Cigelnik, 1997) and Bt2b (Glass and Donaldson, 1995) as previously described by Mostert et al. (2006). *Botryosphaeriaeaceae* isolates were also identified using cultural and morphological characteristics (Van Niekerk et al., 2004). Pure cultures of *Botryosphaeriaeaceae* isolates were subcultured onto water agar (WA, 2% agar) amended with double-autoclaved pine needles and placed under near-UV light for 3 to 5 weeks to induce the pycnidia formation and sporulation. Species of *Botryosphaeriaeaceae* were characterised based on the shape, color, size, presence or absence of septa as well as cell wall structure of conidia. The identity of *Botryosphaeriaeaceae* species was confirmed by sequencing the internal transcribed spacer (ITS) of the nrDNA region using the primer sets ITS1 and ITS4 (White et al., 1990) according to Úrbez-Torres et al. (2008). Genomic DNA was extracted from these isolates using approximately 50 mg mycelium with the Peq Gold Fungal DNA mini Kit following the instructions of the manufacturer. PCR amplifications were performed on a Techne TC-312 Thermal Cycler. Amplification products were analysed by electrophoresis through 1.5% agarose in TAE buffer. PCR products were purified with the High Pure PCR Product Purification Kit (Bioneer, Germany) and sequenced by Bioneer Corporation.
Pathogenicity tests. Excised shoots of quince trees (ranging from 35-40 cm in height and 1.5-2 cm in diameter) were used to assess for the pathogenicity of 17 isolates (5 isolates of *Phaeoacremonium parasiticum*, 3 isolates of *P. viticola*, one isolate of each *P. alvesii* and *P. mortoniae*, 3 isolates of *Dothiorella sarmentorum* and 2 isolates of each *Lasiodiplodia theobromae* and *Diplodia seriata* species). The shoots were surface sterilized with 70% ethanol and left to dry prior to inoculation. A cork borer (4 mm diameter) was used to remove a disk of outer bark of shoots at the site of inoculation. Mycelium plugs (4 mm diameter) were cut from the edges of the growing isolates and inoculated onto the exposed wood. Point-inoculated areas were sealed with Parafilm™ to prevent desiccation of mycelial plugs. Sterile agar plugs served as negative controls. Six excised shoots for each treatment were used and arranged in a randomised block design. The bases of shoots were inserted into bottles filled with water (about 1000 ml) and covered with a transparent plastic bag to prevent evaporation. Inoculated shoots were maintained at room temperature (25 ± 2°C) and lesion lengths produced by inoculated isolates were determined 35 days after inoculation. Re-isolations were made from the margins of the wood lesions and the identity of the isolated fungi was confirmed based on morphology to confirm Koch's Postulates. Analysis of variance (ANOVA) in SAS v 9.1.3 (Service pack 3; SAS Institute, Cary, NC, USA) was performed to evaluate differences in the extent of wood lesions induced by fungal isolates. The mean values of the lesions were compared using Tukey’s test at \( P < 0.05 \).

RESULTS

Sampling and disease symptoms. Thirty-three woody samples were collected from quince trees affected by leaf chlorosis, canker and dieback. On closer examination, brown internal discoloration, central discoloration, wedge-shaped discoloration and brown to black streaking were observed in cross sections of infected branches (Fig. 1). In total, 14 samples showed wood discoloration, 10 have insect holes, and 9 were infested by beetle’s larva. Five adults of *Capnodis tenebrionis* L. (Coleoptera: Buprestidae), 11 adults of *Osphranteria coerulescens* Redtenbacher (Coleoptera: Cerambycidae) and 9 larvae of *O. coerulescens* were also collected and screened for fungal trunk pathogens.

Fungal isolation and identification. A total number of 32 isolates of *Phaeoacremonium* species were obtained, 15 from discolored tissues, 7 from borer holes, 4 from larvae, and 6 from adult beetles. According to their morphological characteristics, these isolates were identified as *P. parasiticum*, *P. viticola*, *P. alvesii* and *P. mortoniae* (Table 1). Based on the BLAST search in GenBank, \( \beta \)-tubulin gene sequences from these isolates had 99-100% of homology with the sequences of related species. *Phaeoacremonium parasiticum*, the most common species, was obtained from discolored woody tissues, borer holes, larvae and adult beetles of *O. coerulescens* and *C. tenebrionis* (Table 1). In total, 8 isolates of *Phaeoacremonium* were identified as *P. viticola*, from discolored woody tissues, borer holes, larvae of *O. coerulescens* and adult of *O. coerulescens*. Two species of *P. alvesii* and *P. mortoniae* only obtained from discolored tissues and borer holes. Co-occurrence of *P. parasiticum* and *P. viticola* on a single sample occurred only once, where both species were isolated from a borer hole. Both *P. parasiticum* and *P. viticola* were also obtained in one case from larvae of *O. coerulescens*. Twenty-two isolates of *Botryosphaeriaceae* were found during this work. Most of these isolates were obtained from discolored tissues (63.6%) followed by borer holes (31.8%) and larvae of *O. coerulescens* (4.6%). Based on their morphological characteristics these
isolates were identified as D. seriata, D. sarmentorum and L. theobromae. Five isolates of D. sarmentorum were obtained, from wedge-shaped discoloration, borer holes and adults of O. coerulescens. 80% of D. seriata isolates were detected from discolored tissues, whereas the remaining isolates were associated with borer holes. Similar results were recorded for L. theobromae. This species was isolated from discolored tissues and borer holes with frequency of 57.1 (4/7) and 42.9% (3/7), respectively. BLAST results from discolored tissues and borer holes with frequency L. theobromae were recorded for D. seriata, whereas the remaining detected from discolored tissues, whereas the remaining isolates were associated with borer holes. Similar results were recorded for L. theobromae. This species was isolated from discolored tissues and borer holes with frequency of 57.1 (4/7) and 42.9% (3/7), respectively. BLAST results for ITS sequences of Botryosphaeriaceae isolates showed an identity of 99-100% with sequences of related species in GenBank. During our survey a number of additional fungi were occasionally isolated, i.e. Fusarium tricinctum, Trichoderma barzianum, Aspergillus spp., Penicillium spp., Paecilomyces sp., Alternaria spp., Phomopsis sp., and Phoma sp. (from discolored tissues and borer holes), Pestalotiopsis sp. and Acremonium sp. (from discolored tissues and larva of O. coerulescens) and other phialidic fungi (from adults of C. tenebrionis and O. coerulescens), which were not considered in this study.

**Pathogenicity tests.** All inoculated isolates were pathogenic on quince shoots and produced lesions significantly (F = 85.14, P<0.0001) greater than control (6.67 mm in average) (Table 2). The lesions caused by L. theobromae isolates were significantly longer (35.67 ± 1.35 mm and 32.33 ± 0.88) than those caused by other species. Two isolates of D. seriata produced smaller lesions (11.67 ± 1.17 and 11.33 ± 0.49 mm) than the other species but still differed significantly from the control (Table 2).

**DISCUSSION**

The species of *Phaeoacremonium* most commonly associated with trunk diseases of pome fruit trees are *P. angustius, P. aleophilum, P. parastictum, P. rubrigenum, P. scolyti, P. mortonae, P. viticola* and *P. iranianum* (Rooney-Latham et al., 2006; Cloete et al., 2011; Arzanlou et al., 2014; Sami et al., 2014). Of these, only *P. aleophilum, P. iranianum, P. rubrigenum, P. scolyti* and *P. parastictum* have recently been isolated and reported from quince trees in Fars (South-western Iran) and Kerman (South-eastern Iran) provinces (Sami et al., 2014) of Iran. Therefore, this study is the first report of *P. viticola and P. mortonae* on this tree species in the world. In our study, three species of *Botryosphaeriaceae, D. seriata, L. theobromae* and *D. sarmentorum* were isolated and identified according to morphological characteristics and ITS data. Various species of this family such as Diplodia bulgarica, Diplodia malorum, Diplodia mutila, D. sarmentorum, Neofusisococcum australae, Neofusisococcum parvum, Diplodia intermedia, Neoscytalidium hyalinum, Neofusisococcum vitifusiforme and Dothiorella iberca have previously been isolated and reported from apple and pear trees (Sutton and Dyko, 1989; Gadgil et al., 2005; Phillips et al., 2005; Slippers et al., 2007; Shen et al., 2010; Cloete et al., 2011; Phillips et al., 2012; Adesmoye et al., 2013). Of these only *D. intermedia* has been reported on the genus of *Cydonia* (Phillips et al., 2012), therefore this is the first report of *D. seriata, L. theobromae* and *D. sarmentorum* on this tree species in the world.

Present survey has shown that larvae of *O. coerulescens* and adult beetles of *O. coerulescens* and *C. tenebrionis* can carry two *Phaeoacremonium* spp. namely, *P. parastictum* and *P. viticola*. These results are consistent with previous studies, which have shown that different arthropods are capable of vectoring *Phaeoacremonium* species (Kubátová et al., 2004; Moyo, 2013). Arthropods can disperse fungal conidia of different taxa including imperfect fungi, ascomycetes and basidiomycetes (Ingold, 1953; Kendrick, 1985). Numerous studies have been shown that mites (Talbot, 1952; Roets et al., 2006; 2011), springtails (Talbot, 1952; Lilleskov and Bruns, 2005), beetles (Belhoucine et al., 2011; Lilleskov and Bruns, 2005), millipedes and ants (Van der Meer et al., 1990; Moyo, 2013) can play a role in the dissemination of different fungal pathogens. In this regards, beetles have been shown to transmit numerous plant fungal pathogens (Juzwik et al., 2004; Kubátová et al., 2004, 2005; Avgiou, 2005). Insects can disperse fungal spores when coming into contact with conidial heads, sticky

### Table 1. Identity and frequency of fungi isolated from internal wood discoloration, larvae and adult beetles collected from quince trees orchards.

<table>
<thead>
<tr>
<th>Fungal species</th>
<th>Number (%)</th>
<th>Discolored woody tissues</th>
<th>Borer holes</th>
<th>Larvae</th>
<th>Adults of <em>O. coerulescens</em></th>
<th>Adults of <em>C. tenebrionis</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>BID</td>
<td>WSD</td>
<td>BBS</td>
<td>CD</td>
<td></td>
</tr>
<tr>
<td><em>P. parastictum</em></td>
<td>21 (38.89)</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><em>P. viticola</em></td>
<td>8 (14.82)</td>
<td>1</td>
<td>–</td>
<td>1</td>
<td>–</td>
<td>2</td>
</tr>
<tr>
<td><em>P. alveii</em></td>
<td>2 (3.70)</td>
<td>1</td>
<td>–</td>
<td>1</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><em>P. mortonae</em></td>
<td>1 (1.85)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><em>D. sarmentorum</em></td>
<td>5 (9.26)</td>
<td>–</td>
<td>2</td>
<td>–</td>
<td>–</td>
<td>2</td>
</tr>
<tr>
<td><em>L. theobromae</em></td>
<td>7 (12.96)</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>–</td>
<td>3</td>
</tr>
<tr>
<td><em>D. seriata</em></td>
<td>10 (18.52)</td>
<td>3</td>
<td>4</td>
<td>–</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>54 (100.00)</td>
<td>10</td>
<td>9</td>
<td>5</td>
<td>5</td>
<td>14</td>
</tr>
</tbody>
</table>

* a = Discolored woody tissues of infected branches in cross section; BID = brown internal discoloration, WSD = wedge-shaped discoloration, BBS = brown to black wood streaking, CD = central discoloration. b = Larvae of *Osphranteria coerulescens.*
spores and spore droplets. *Phaeoacremonium* spp., as hyphomycetes fungi, produce conidia that can be dispersed aerially and usually infect the host by pruning wounds (Gubler et al., 2001) however, in light of the results of this study it seems plausible that *Phaeoacremonium* can also be vectored by beetles. Edwards et al. (2001) reported an association of collombolans and mites with sporulating structures of *Pa. chlamydospora* on grapevines in Australia. According to Rooney-Latham et al. (2005), wood-boring insects might play a role in the dispersal of *Togonia minima* (anamorph *P. aleophilum*) as the most important fungal trunk pathogen associated with grapevine. *Phaeoacremonium rubrigenum* has been isolated from larvae and galleries of oak bark beetles (*Scolytus intricatus*, *Scolytinae*) on oak trees (*Quercus robur* L.). This species has been also isolated and reported from adults of *Leperisinus fraxini*, *Scolytinae*, on ash trees (Kubátová et al., 2004). *Phaeoacremonium mortoniae* has been isolated from discolored woody tissues of *Fraxinus pennsylvanica* in North Dakota, which also had larval galleries of *Leperisinus californicus* (Hausner et al., 1992). Moyo (2013) reported *P. sicilianum*, *T. minima*, *P. alvesii* and *P. parasiticum* associated with arthropods in South Africa vineyards.

Of *Botryosphaeriaceae* spp., only *D. sarmentorum* was recovered from adult beetles of *O. coerulescens* during this study. It has previously been shown that several insects can carry viable propagules of *Botryosphaeriaceae* spp. In this regards, some species of *Botryosphaeriaceae* including *Diplodia medicani*, *Aplosporella prunicola* and *Diplodia scrobiculata*, which are pathogens on *Prunus* spp. (Damm et al., 2007), *Medicago sativa* (Phillips et al., 2008) and *Pinus* spp. (Bihon et al., 2011), have also been recovered from arthropods. During an investigation by Epstein et al. (2008) in California vineyards, *D. seriata* was found on rove beetles collected from pruning wounds. *Aplosporella prunicola*, *D. scrobiculata*, *D. seriata*, *N. australis*, *N. parvum* and *Spencermartinsia viticola* have recently also been isolated from various arthropods in South African vineyards (Moyo, 2013).

Many *Botryosphaeriaceae* and *Phaeoacremonium* spp. have been reported to be associated with arthropods but there have been no studies on the pathogenicity of these species on the main hosts. Our results showed that inoculated isolates obtained from discolored woody tissues, borer holes, larvae and adult beetles were pathogenic on quince shoots. Of the seven species tested on quince shoots in this study, the lesions caused by *L. theobromae* were longer than those caused by the other species. These results are consistent with previous pathogenicity tests conducted in California, Mexico and South Africa, in which *L. theobromae* was shown to be one of the most virulent *Botryosphaeriaceae* species tested on grapevine (Van Niekerk et al., 2004; Úrbez-Torres et al., 2008; Úrbez-Torres and Gubler, 2009).

*Osphranteria coerulescens* is the most destructive pest of various trees such as apple, pear, quince, Japan quince, almond, apricot, peach, cherry, rose, oak, eucalyptus and some ornamental plants in Iran (Modarres Awal, 1997; Aghaali et al., 2012). In this regard, *C. tenebrionis*, as an important pest, can attack different fruit trees including almond, apricot, cherry, nectarine, peach and plum trees (Ben-Yehuda et al., 2000). Many species of twig beetles have multiple hosts and likely contribute to the transmission of fungal trunk pathogens to other than the main host. The presence of

![Table 2. Mean lesion length and re-isolation frequencies of fungal isolates inoculated onto detached quince shoots in a pathogenicity test.](https://example.com/table.png)

<table>
<thead>
<tr>
<th>Fungal Isolates inoculated</th>
<th>Identity</th>
<th>Accession numbers</th>
<th>Original substrate</th>
<th>Mean lesion length (mm) ± SE</th>
<th>Re-isolation frequency %</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. parasiticum</em></td>
<td>KER-U- PRPH83</td>
<td>–</td>
<td>Discolored woody tissues</td>
<td>25.17 ± 0.51 b</td>
<td>87.50</td>
</tr>
<tr>
<td></td>
<td>KER-U- PRPH82</td>
<td>–</td>
<td>Borer holes</td>
<td>19.17 ± 0.83 def</td>
<td>87.50</td>
</tr>
<tr>
<td></td>
<td>KER-U- PRPH76</td>
<td>KM676445</td>
<td>Larvae (<em>Osphranteria coerulescens</em>)</td>
<td>22.67 ± 0.73 bcd</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>KER-U- PRPH78</td>
<td>KM676447</td>
<td>Adult beetles (<em>Osphranteria coerulescens</em>)</td>
<td>24.83 ± 0.89 bc</td>
<td>62.50</td>
</tr>
<tr>
<td></td>
<td>KER-U- PRPH77</td>
<td>KM676446</td>
<td>Adult beetles (<em>Capnodis tenebrionis</em>)</td>
<td>20.83 ± 1.15 cde</td>
<td>50.00</td>
</tr>
<tr>
<td><em>P. viticola</em></td>
<td>KER-U- PVPH79</td>
<td>KM676449</td>
<td>Discolored woody tissues</td>
<td>15.50 ± 0.32 fgh</td>
<td>87.50</td>
</tr>
<tr>
<td></td>
<td>KER-U- PVPH81</td>
<td>KM676448</td>
<td>Borer holes</td>
<td>14.83 ± 0.25 ghi</td>
<td>62.50</td>
</tr>
<tr>
<td></td>
<td>KER-U- PVPH80</td>
<td>KM676450</td>
<td>Larvae (<em>Osphranteria coerulescens</em>)</td>
<td>16.35 ± 1.01 fg</td>
<td>62.50</td>
</tr>
<tr>
<td><em>P. alvesii</em></td>
<td>KER-U- PLPH74</td>
<td>KM676443</td>
<td>Discolored woody tissues</td>
<td>14.66 ± 1.0 ghi</td>
<td>37.50</td>
</tr>
<tr>
<td><em>P. mortoniae</em></td>
<td>KER-U- PMPH75</td>
<td>KM676444</td>
<td>Discolored woody tissues</td>
<td>16.67 ± 0.71 ghi</td>
<td>62.50</td>
</tr>
<tr>
<td><em>D. sarmentorum</em></td>
<td>KER-U- DOSKB63</td>
<td>–</td>
<td>Discolored woody tissues</td>
<td>18.50 ± 0.51 ef</td>
<td>87.50</td>
</tr>
<tr>
<td></td>
<td>KER-U- DOSKB57</td>
<td>KM676437</td>
<td>Borer holes</td>
<td>19.17 ± 0.81 def</td>
<td>87.50</td>
</tr>
<tr>
<td></td>
<td>KER-U- DOSKB58</td>
<td>KM676438</td>
<td>Adult beetles (<em>Osphranteria coerulescens</em>)</td>
<td>17.00 ± 1.32 ef</td>
<td>50.00</td>
</tr>
<tr>
<td><em>L. theobromae</em></td>
<td>KER-U- LTKB60</td>
<td>KM676440</td>
<td>Discolored woody tissues</td>
<td>35.67 ± 1.35 a</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>KER-U- LTKB61</td>
<td>KM676441</td>
<td>Borer holes</td>
<td>32.33 ± 0.88 a</td>
<td>87.50</td>
</tr>
<tr>
<td><em>D. seriata</em></td>
<td>KER-U- DSKB59</td>
<td>KM676442</td>
<td>Discolored woody tissues</td>
<td>37.67 ± 0.43 i</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>KER-U- DSKB62</td>
<td>KM676442</td>
<td>Borer holes</td>
<td>11.67 ± 1.17 hi</td>
<td>87.50</td>
</tr>
<tr>
<td>PDA plug</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>6.67 ± 0.42 j</td>
<td>–</td>
</tr>
</tbody>
</table>

a = Culture collection of Plant Protection Department, Faculty of Agriculture, Shahid Bahonar University of Kerman, Kerman, Iran.

b = Means with the same letter are not significantly different.
these fungi on *O. coerulescens* and *C. tenebrionis* suggests that these beetles may transport pathogens between different woody hosts, especially where these hosts occur in close proximity. In Iran, pome fruit trees are planted around or near stone fruit trees and grapevines, therefore insects might transport the pathogens between these woody fruit crops. Further studies are required to determine the role of other arthropod taxa in the dispersal of trunk pathogens associated with fruit trees and grapevines in orchards and vineyards.

REFERENCES


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