

Pathogen exclusion: Options and implementation

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Many of the most destructive pathogens of avocado have been widely disseminated. *Phytophthora cinnamomi* causes serious problems worldwide, *Colletotrichum gleosporioides* is a problem in virtually all humid production areas, and diverse ascomycetes cause post-harvest problems in many areas. Due to the wide geographic distributions of these pathogens, pathogen exclusion is usually not an option for managing the diseases that they cause.

In contrast, some pathogens of avocado have restricted distributions. *Raffaelea lauricola*, cause of laurel wilt, *Sphaceloma perseae*, cause of scab, and *Xylella fastidiosa*, cause of leaf scorch, are notable examples of avocado pathogens that have moderately to highly localized distributions. Although management of the diseases that they cause can be difficult, their limited ranges indicate that a most effective measure, pathogen exclusion, is possible. We review the threats that localized pathogens pose to avocado production, and discuss measures to ensure that such pathogens are not disseminated.

Exclusión de patógenos: Opciones e implementación

Muchos de los patógenos más destructivos del aguacate han sido diseminados ampliamente. *Phytophthora cinnamomi* causa problemas graves a nivel mundial, *Colletotrichum gleosporioides* es un problema en casi todas las áreas de producción húmeda, y diversos ascomicetas causan problemas de postcosecha en muchas áreas. Debido a la gran distribución geográfica de estos patógenos, normalmente, excluirlos no es una opción para controlar las enfermedades que causan.

En contraste, algunos patógenos del aguacate tienen distribuciones restringidas. *Raffaelea lauricola*, que causa la marchitez del laurel, *Sphaceloma perseae*, que causa roña, y *Xylella fastidiosa*, que causa quemadura de las hojas, son ejemplos notables de patógenos del aguacate que tienen distribuciones de moderada a altamente localizadas. Aunque el manejo de las enfermedades que causan puede ser difícil, su distribución limitada indica que una medida de lo más efectiva, la exclusión del patógeno, es posible. Examinamos las amenazas que los patógenos con distribución limitada posan a la producción de aguacate, y discutimos medidas para asegurarnos de que tales patógenos no son diseminados.

Keywords: laurel wilt, *Raffaelea lauricola*, *Xyleborus glabratus*, sunblotch, Avocado sunblotch viroid, scab, *Sphaceloma perseae*, leaf scorch, *Xylella fastidiosa*, pathogen exclusion

Introduction

Diseases are among the most important constraints to avocado production worldwide (Dann *et al.* 2011, Menge and Ploetz 2003). The most important disease, Phytophthora root rot, is the limiting factor in many avocado-producing regions, and there are many other diseases that can have a significant impact on this crop, including anthracnose, Phytophthora cankers, Pseudocercospora spot, Rosellinia root rot, and stem-end rot. In general, these diseases require expensive chemical and cultural interventions.

In contrast, other diseases of avocado have relatively restricted distributions or have only recently emerged as problems on this crop. For example, laurel wilt, caused by *Raffaelea lauricola*, is known only in Florida (USA) (Ploetz *et al.* 2011), and leaf scorch, caused by *Xylella fastidiosa*, has been reported only in Costa Rica (Montero-Astúa *et al.* 2008). Brown root rot, caused by the widespread tropical fungus *Phellinus noxiosus*, has only recently caused damage on avocado in Australia (Dann *et al.* 2011). Some diseases, such as Phytophthora cankers, and stem-end and post-harvest rots, have multiple causal agents, only some of which are widely distributed. And other diseases are not found in all of the major production areas. For example, scab, caused by *Sphaceloma perseae*, is not present in Australia or New Zealand (Everett 2008), and sunblotch, caused by Avocado sunblotch viroid, has been successfully interdicted in some areas after effective roguing and clean-scion campaigns (Geering 2011, Schnell *et al.*

1997). In general, few of the pathogens that affect avocado are found in most of the areas where this crop is grown.

Despite their limited distributions, the latter diseases can have serious impacts on production. Laurel wilt kills trees rapidly, and would cause serious problems if it spread to avocado-production areas outside Florida (Evans *et al.* 2010, Ploetz *et al.* 2011). Other, nonlethal diseases of avocado have trade implications. For example, market access for fruit from scab-affected areas is reduced or eliminated in scab-free areas (Everett, 2008).

Pathogen exclusion is an essential objective when managing diseases with limited distributions (Ploetz 2007). Disease management is always more expensive and difficult once a pathogen has been introduced into a new area: eradication is often impossible; chemical inputs are not available or are costly and unwanted additions to crop management schemes; disease-resistant genotypes are not available, developed or productive; and cultural measures may be time-consuming and not very effective.

We discuss the exclusion of avocado pathogens below. Rather than review the long list of these pathogens, we focus on four examples that have different life cycles and epidemiologies; each could move easily to pathogen-free areas. Two fungi are profiled, one of which, *R. lauricola*, has an insect vector and systemically infects avocado and other species in the Lauraceae plant family, whereas the other, *S. perseae*, does not have a vector and is not systemic. The Avocado sunblotch viroid is reviewed as a systemic and often symptomless pathogen of avocado, and the bacterium *X. fastidiosa* is covered as a new avocado pathogen with unclear vector relations, host range and approaches to management.

Laurel wilt, caused by *Raffaelea lauricola*

Laurel wilt affects plants in the Lauraceae, especially species that are native to the Western Hemisphere. Its Asian ambrosia beetle vector, *Xyleborus glabratus*, was introduced into Port Wentworth, GA, USA in 2002 (Fraedrich *et al.* 2008). It and laurel wilt have since spread throughout the Southeastern Coastal Plain of the USA, and now extend as far south as southern Florida and as far west as Mississippi. Avocado was first recognized as a host of laurel wilt in 2006 (Mayfield *et al.* 2008b). Despite its restricted distribution, laurel wilt has caused significant concern due to its lethal impact and a large number of unknowns that surround its epidemiology and management.

Symptoms. Initially, affected trees wilt rapidly, often in only a portion or one branch of a tree. Leaves become an oily green as they wilt and then a dry brown as they die. Defoliation usually occurs within 3–4 months. Symptoms spread throughout the canopy, and although trees may re-sprout from the base, they often die. Internally, affected sapwood is a reddish brown colour which often has a greyish caste.

In general, the above symptoms resemble those of Verticillium wilt (caused by *Verticillium dahliae*). However, complete recovery of trees from Verticillium wilt is common, whereas those affected by laurel wilt often die. Eventually, trees affected by laurel wilt become brood trees for *X. glabratus* and other ambrosia beetle species that produce conspicuous frass on the trunk of colonized trees. Diagnosis of laurel wilt relies on the identification of *X. glabratus* in affected trees or DNA tests for *R. lauricola*.

Causal agent. *Raffaelea lauricola*, an ascomycete, causes laurel wilt (Harrington *et al.* 2008). It is a symbiont of *X. glabratus*, females of which carry it in specialized compartments, mycangia, from one tree to another (Fraedrich *et al.* 2008, Harrington *et al.* 2008). Broods of *X. glabratus* in colonized host trees subsist on lawns of this fungus that females cultivate in the natal galleries.

Raffaelea lauricola is related to other ambrosia fungi and ophiostomoid plant pathogens (e.g., *Ophiostoma novo-ulmi*) (Alamouti *et al.* 2009; Harrington *et al.* 2008). PCR primers for SSU rDNA have been used to detect the pathogen in conventional and realtime PCR assays (Dreaden *et al.* 2008). With one exception ("Raffaelea sp. 272"), these primers have specifically identified *R. lauricola* in diagnostic and experimental work (Dreaden and Smith, unpublished; Ploetz, unpublished). Recently, microsatellites have been developed that distinguish *R. lauricola* from *Raffaelea* sp. 272 and other close relatives of this fungus (Dreaden and Smith, unpublished). Their use in an improved diagnostic assay will enable rapid and accurate detection of this pathogen and laurel wilt.

Epidemiology. Laurel wilt is an unusual disease. Ambrosia beetle symbionts are typically saprobes, but *R. lauricola* is a virulent and systemic pathogen. Ambrosia beetles are also usually attracted to stressed or dead trees, yet *X. glabratus* is sufficiently attracted to healthy trees to initiate infection. In avocado and other host species, females of *X. glabratus* that vector the pathogen are thought to make exploratory probes in healthy trees (Fraedrich et al. 2008, Harrington et al. 2008). Although these initial contacts do not start colonies of the beetle, they result in systemic infection of trees. As infected trees decline, they become more attractive to females of *X. glabratus*, which eventually develop broods in them. Subsequent generations of females that are produced in affected trees are responsible for the primary, epidemic movement of this disease.

Others means by which this disease could spread are less well understood. Anthropogenic movement of affected logs has been implicated at least four times in the long-distance spread of the disease on redbay (*Persea borbonia*), a native host that has been decimated in the SE USA (e.g., Chemically Speaking, 2009). Based on observations in the field and the root graft movement of similar pathogens (e.g., *O. novo-ulmi* and *Ceratocystis fagacearum*), it is probable that *R. lauricola* is also transmitted via root grafts. Transmission of *R. lauricola* via pruning tools, seed and fruit appears to be unlikely (Beckman et al. unpublished data, Ploetz et al. unpublished data).

At least 15 ambrosia beetle species have been identified in avocado trees in South Florida (Peña et al. unpublished). Although only *X. glabratus* has been shown to vector *R. lauricola*, the numbers of this species that have been recovered from avocado are quite low relative to redbay (Peña et al. unpublished). In this regard, avocado appears to be a relatively poor host: only 4 of 1,000 scolytids that emerged from laurel wilt-affected avocado bolts were *X. glabratus*, whereas 980 of 1,000 that emerged from redbay were of this species (Peña et al. unpublished). Although reasons for these results are not clear, they could have important implications for whether laurel wilt epidemics could develop in avocado in the absence of redbay or other more preferred hosts.

In general, ambrosia beetles were presumed to have close associations with one or only a few symbiotic fungi (Batra 1967). However, the recovery of six different species of *Raffaelea* from *X. glabratus* by Harrington and Fraedrich (2010) indicates that this presumption is incorrect, at least for this species. Moreover, symbionts are not necessarily restricted to a single species of ambrosia beetle (Batra 1967) and the lateral transfer of a symbiont species from one beetle species to another has been reported (Gebhardt et al. 2004). Thus, Harrington & Fraedrich (2010) and Kendra et al. (2011) suggested that *R. lauricola* might have ambrosia beetle vectors other than *X. glabratus*. Ott (2007) determined that *R. lauricola* did not establish in the mycangia of *Xylosandrus crassiusculus*, but it has been recovered from *Xyleborinus saxeseni* (Ratzeburg) (Harrington et al. 2010a, Fraedrich et al. 2011), and *Xyleborus affinis* Eichhoff. and *Xyleborus ferrugineus* (F.) (Ploetz et al. unpublished data). To date, the infestation and inoculation of healthy avocado, redbay or other laurel wilt hosts by these species has not been demonstrated.

More work is needed to clarify the significance of these findings and whether species other than *X. glabratus* might also obtain and transmit this pathogen. The unique relationship between *R. lauricola* and *X. glabratus* in Asia may indicate that only *X. glabratus* would be an important vector (Harrington et al. 2011). Since they usually do not infest living trees, ambrosia beetles other than *X. glabratus* that are colonized by *R. lauricola* may not pose a threat to avocado. However, outside the native range of *X. glabratus* they may become reservoirs for *R. lauricola*. The role of ambrosia beetles other than *X. glabratus* in the persistence of this pathogen in newly infested areas is an important topic for future study. Work is needed to determine how this might impact laurel wilt epidemics in avocado monocultures, and whether other ambrosia beetle species are capable of vectoring *R. lauricola* to healthy avocado trees.

Management. The value of pathogen and vector exclusion is clear from the history and rapid spread of laurel wilt in the Western Hemisphere. In less than a decade, the disease has become so widely established in the Southeastern Coastal Plain that its eradication in the USA is not possible.

Eradication of laurel wilt in a newly affected area has been attempted only once, albeit unsuccessfully (Mayfield et al. 2009). In that situation, symptomatic redbay trees were removed but the disease quickly

reappeared. How sanitation (either removing dead trees or dead branches on affected trees) would impact the development of laurel wilt in avocado monocultures is not known.

To date, avocado mortality has been evident wherever there are significant populations of brood trees for *X. glabratus* (e.g., redbay or swampbay). Whether epidemics would develop in avocado monocultures in the absence of brood trees, and whether interactions of *X. glabratus* and avocado would increase after populations of brood trees were reduced by laurel wilt are unknown.

Scab, caused by *Sphaceloma perseae*

Scab, caused by *Sphaceloma perseae*, is a serious problem in humid avocado-growing regions, such as Florida, Latin America, Morocco, Philippines and South Africa. To date, it has not been found in Australia and New Zealand (Everett 2008).

Symptoms. Severe losses result from fruit drop and the lowered market value of affected fruit. Fruit spots are initially oval to irregular in shape, brown to purple-brown, and slightly raised with a sand paper-like surface (Pohronenzy and Simone 1994). As the disease progresses, spots enlarge and coalesce. Often there are intersecting raised ridges, and large rough, corky areas may form over the surface of the fruit.

Lesions on leaves are less conspicuous because they are often high in the tree canopy. They are initially less than 3.5 mm diameter and become necrotic and brown to black. They are usually concentrated along leaf veins and cause leaves to become stunted, crinkled and distorted. Lesions may coalesce into star-like patterns and shot holes develop in the leaves. Raised, corky, roughened, oval to elongate lesions also occur on twigs and pedicels.

Although they are similar in appearance, symptoms of scab can be distinguished from those caused by physical abrasion.

Causal agent. *Sphaceloma perseae* produces acervuli that erupt from leaves or fruit lesions as small, white, cream to olive masses of clustered conidiophores and spores (Jenkins 1934, Pohronenzy and Simone 1994). Conidiophores are 12 to 100 µm in length and bear conidia along their tips or sides. Conidia are colourless, aseptate, ovoid to strongly curved and 2-30 x 2-5 µm. On PDA, the fungus produces white to dark grey mycelium.

Epidemiology. During cool, moist weather, conidia may be formed on infected leaves, twigs and fruit. They are carried to infection courts by wind, rain and insects (Teliz 2000). In Mexico, most spores were produced in the winter prior to active growth, while most lesions were found 6 months later after the fruit set and foliage flush (Teliz 2000).

Sphaceloma perseae is a pathogen of young tissue. Leaves become resistant 1 month after emergence and fruit become resistant once they are half-grown (Pohronenzy and Simone 1994). Disease is most severe when host tissue is at a susceptible growth stage and heavy rains or foggy weather keep the humidity above 80% (Teliz 2000). Injuries caused by thrips create entry wounds for *S. perseae* and greatly exacerbate scab development.

Cultivars vary in their reaction to scab. ‘Lula’ is now seldom planted in Florida because of its extreme susceptibility. ‘Booth 3, 5, 7, and 8’, ‘Choquette’, ‘Fuerte’, ‘Hass’, ‘Monroe’, and ‘Trapp’ are moderately susceptible, whereas ‘Booth 1’, ‘Collins’, ‘Pollack’ and ‘Waldin’ are somewhat resistant (Pohronenzy and Simone 1994).

Management. Scabby fruit, which are left on the tree during harvest, often become primary sources of inoculum the following year. Thus, scabby fruit should be removed from the grove. *Sphaceloma perseae* is probably moved most effectively on infected fruit, but could also be moved in infected scion material.

Sunblotch, caused by *Avocado sunblotch viroid*

Avocado sunblotch, caused by *Avocado sunblotch viroid* (ASBVd), was first recorded in California (Horne and Parker, 1932) and has subsequently been reported in many avocado-growing areas. It is possible that ASBVd is more widespread because sunblotch symptoms vary and symptomless carriers of ASBVd are common (Schnell *et al.* 2001). Sunblotch is considered a minor problem in countries where tree

registration programs exclude ASBVd from propagating material (Dann *et al.* 2011), but can become widespread where effective measures are not used or available.

Symptoms. The symptoms of avocado sunblotch vary considerably and are influenced by host cultivar, the environment and the strain of ASBVd that infect a given plant (Dale *et al.* 1982, Desjardins *et al.* 1987, Schnell *et al.* 2001, Semancik 2003, Semancik and Szychowski 1994). Typical symptoms usually include discolored and depressed stem streaks, grooves on older branches, lesions and discoloration of the fruit, and diverse foliar symptoms. Importantly, some infected trees remain symptomless.

The most consistent initial symptom of sunblotch infection is the appearance of narrow white, yellow or pink streaks, on the surface or slightly depressed, along green twigs or young stems. On leaves, bleached or chlorotic areas may form initially around the leaf veins and this may progress to complete chlorosis or bleaching with leaves becoming deformed. Leaf symptoms in the field are uncommon. Fruit produced from infected trees usually develop sunken white, yellow or pink blotches or streaks and are usually small, deformed and unmarketable. The bark on the trunk or larger branches can have a rectangular cracked appearance, often referred to as "crocodile skin" or "alligator bark." The symptoms of sunblotch may be irregularly distributed throughout an infected tree. Severely affected trees are often stunted, sparsely foliated and develop a sprawling, prostrate architecture.

Trees with symptoms can quickly become asymptomatic. Symptomless trees may develop typical symptoms following stress induced by severe pruning as part of canopy management. All infected trees, symptomless or not, usually have greatly reduced yields.

Causal agent. *Avocado sunblotch viroid* (ASBVd) is a circular, single-stranded RNA of between 246 and 251 nucleotides (Pallas *et al.* 1988; Rakowski and Symons 1989; Semancik and Szychowski 1994). Small changes in the nucleotide sequence of the viroid can have a dramatic effect on symptom expression. Sequence variants have been categorized according to their association with the different symptom types: those associated with bleached, variegated and asymptomatic tissues have been labeled ASBVd-B, -V, -SC, respectively (Semancik and Szychowski 1994). Trees with initially severe leaf bleach symptoms can recover over time and become symptomless carriers but following severe pruning, leaf bleach symptoms may return (Semancik 2003). Conversion of ASBVd-SC to ASBVd-B is correlated with the addition of a single U between nucleotides 115 and 118 in the viroid genome (Schnell *et al.* 2001).

ASBVd can be detected using molecular methods or by grafting bark patches onto indicator hosts such as young Mexican seedlings. Molecular methods include DNA probes and a highly sensitive reverse transcriptase polymerase chain reaction (RT-PCR) assay that is capable of detecting as little as 1 ng of ASBVd in plant tissue extracts (Schnell *et al.* 1997).

Epidemiology. ASBVd is systemic in avocado trees but its concentration can vary widely among branches. It has no known insect vector and the principal means of transmission are in seed used to propagate rootstocks, in scion material used for grafting, and via root grafts. Sunblotch is transmitted, although inefficiently, on sap-contaminated pruning blades, harvesting clippers and injection equipment. ASBVd is transmitted in pollen, but only the developing fruit, and not the fruit-bearing tree, are infected.

Symptomless carrier trees play an important role in the epidemiology of sunblotch disease. Seed transmission of ASBVd occurs at a much higher frequency (80-100%) in symptomless infected trees than in trees displaying symptoms (up to 5%). Furthermore, plants grown from the seed of a symptomless carrier tree remain symptomless whereas those grown from seed from symptom-bearing trees display characteristic symptoms (Wallace and Drake 1962).

Management. The most important control measure for sunblotch is the careful selection of pathogen-free budwood and seed that are used for propagation. The highly sensitive RT-PCR assay should be used to ensure the pathogen-free status of propagation sources (Schnell *et al.* 1997).

The disease can also be controlled by removing symptomatic and symptomless trees from orchards and indexing suspect trees. Infected trees, and those within a 15-m radius, must be destroyed. Pruning tools,

harvesting clippers and injection equipment should be thoroughly cleaned and then disinfested by dipping in a solution of sodium hypochlorite (1.5%) when working between trees.

Leaf scorch, cause by *Xylella fastidiosa*

This new and apparently minor problem was first observed in the late 1990s in Costa Rica (Montero-Astúa *et al.* 2008). Canopies of affected trees exhibited the following symptoms nonuniformly: deformed leaves with scorched margins, chlorotic mottling, defoliation, shortened internodes, and branch dieback.

With specific antiserum and double-antibody sandwich (DAS)-ELISA, the bacterium *Xylella fastidiosa* was detected in 188 of 227 avocado trees that were tested from 2000–2004. Detection in individual trees varied with the season and the branches that were tested. Graft-transmission of leaf scorch symptoms was achieved in eight of 15 trees in which infected budwood was grafted on ELISA-negative avocado seedlings. The pathogen was detected via nested PCR in two of the grafted seedlings and seven field trees from the Alajuela and San José provinces. PCR products from grafted seedlings (one) and field trees (three) were cloned and sequenced; GenBank sequences EU021997 to EU022000 were a 99 to 100% match for a Pierce's disease strain of *X. fastidiosa* from California (Temecula1) and 94 to 95% to a citrus variegated chlorosis strain from Brazil (Found-5).

Xylella fastidiosa was known previously in Costa Rica on coffee and citrus, hosts of this pathogen that are widespread in tropical America. Thus, this disease may appear in other avocado-growing areas in the region in the future. Why the disease has not appeared in California, where Pierce's disease is now widespread, is not clear.

Epidemiological principles

The successful management of plant disease utilizes several principles and practices, regardless of the host and environment in which it is grown (Palti 1981). These include the avoidance, exclusion and eradication of the causal agents. Host protection is of great importance, as is the identification and incorporation of resistance in the host plant.

In general, effective disease management relies on a delay in the onset or reduction in the initial levels of disease (x_0), or a reduction in the rate at which disease develops over time (r). Diverse tactics exist for the exclusion of plant pathogens. Although the idea that "there is no disease without the pathogen" is a simple one, excluding pathogens from production areas ($x_0=0$) can be a difficult. However, when it is possible exclusion is a most cost-effective disease management strategy.

The early detection and accurate identification of pathogens are often important first steps in exclusion, and the certification of pathogen-free status and safe movement of germplasm rely on their success. Long distance dispersal (LDD) of some pathogens can occur naturally, but human intervention is necessary for most (Ploetz 2007). Quarantines can be an important first line of defense against their intended or unintended movement, and most countries have lists of forbidden or restricted pathogens and host plants. Unfortunately, enforcing these rules to ensure border safety is not always possible. The recent accidental introduction of *Xanthomonas axonopodis* pv. *citri* into citrus-growing areas in Florida and Queensland, Australia are good examples of the anthropogenic dissemination of harmful plant pathogens. The removal of trade barriers may also be problematic; the concerns that nonendemic pathotypes of *Guignardia musae* and *Ralstonia solanacearum* might be introduced into Australia if Philippine bananas are shipped to this country are examples.

Pathogens that are moved in debris and on machinery, tools and other implements can be excluded by surface disinfection with chemical and physical measures. Likewise, seed and planting material can be treated to kill pathogens. Heat treatment (thermotherapy) of vegetative propagation materials is useful against some bacteria, fungi, nematode and viruses. For example, the burrowing nematode, *Radopholus similis*, can be eliminated from banana suckers by hot water treatment. Some pathogens can be eliminated from true seed, especially if contamination is restricted to the seed exterior. Although heat treatment is also used for this purpose, surface disinfection with chlorine or fungicides is most frequent. Pathogen vectors can also be eliminated to exclude pathogens of concern, but this is often a difficult objective.

Recommendations

Excluding important pathogens of avocado from unaffected production areas depends on the specific pathogen and area to be protected. None of the pathogens that were discussed above are capable of natural LDD (without human intervention). Thus, recognizing the pathways by which humans would and could move these pathogens are key. In general, quarantine agencies and the resident avocado industries need to monitor the movement of propagation materials and germplasm into a given area. Although specific guidelines for avocado do not exist, technical guidelines for other crop species provide good examples of what should be considered when moving crop germplasm (Bioversity 2011).

With the possible exception of *R. lauricola*, each of the avocado pathogens that were used as examples above are capable of moving in budwood. Thus, precautions would need to be taken when importing scion material from affected areas into those in which ASBVd, *S. perseae* and *X. fastidiosa* are not known or in which they have been eliminated. Molecular diagnoses of these pathogens (ASBVd and *X. fastidiosa*) or post-entry quarantine (*S. perseae*) would be needed to ensure that new germplasm was not infected with these pathogens.

Although accurate molecular diagnostics are still being developed for *R. lauricola*, they may not be needed when considering the movement of avocado germplasm and this pathogen. In preliminary work, *R. lauricola* did not infect avocado seed or fruit (Ploetz *et al.* unpublished). Although ongoing work will determine whether it can move in budwood, the rapid development of laurel wilt symptoms in infected plants suggests that budwood transmission of this pathogen is a remote possibility. However, as is indicated by the outbreak of laurel wilt in the Southeastern USA, the vector of *R. lauricola*, *X. glabratus*, is capable of moving long distances, presumably in wooden packing materials that are used in maritime trade.

The recent emergence of laurel wilt and other ambrosia beetle-associated tree pathogens/diseases is of concern. Given the typical biology of these symbioses, these problems would have not been expected scarcely a decade ago (Hulcr and Dunn 2011). Unfortunately, we will probably be unable to predict future outbreaks of such problems, even with the increased awareness that they do occur.

Knowledge of what destructive avocado pathogens exist, where they are found, and how they can be disseminated and interdicted are essential to ensure the ongoing production of avocado in a region. As new diseases arise in global agriculture it should be assumed that new problems will become evident on avocado, those that could not have been predicted nor for which effective management strategies exist. Laurel wilt, brown root rot, and leaf scorch are but a few examples of avocado diseases that were unknown only a short while ago (e.g. Menge and Ploetz 2003, Pegg *et al.* 2002).

Although it would not be possible to prepare for specific new threats until they arose, it would be useful to develop a global awareness that these problems develop. Furthermore, a greater awareness is needed that the international movement of vegetative materials and seed of this crop comes with inherent risks. Guidelines for the safe movement of avocado germplasm should be developed.

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