Topics in Subtropics Newsletter

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News from the Subtropical Tree Crop Farm Advisors in California

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A “boring” problem that’s generating big interest in southern California

By Deena Husein, UCR Entomology, Ph.D. Candidate, Stouthamer Lab

It has been a little over a decade since the first sighting of the polyphagous shot hole borer (PSHB) in Los Angeles County, yet a reliable control method has not been established. Part of the setback was caused by the misidentification of the species due to the beetle having a similar appearance to a low-risk pest — the tea shot hole borer. Aside from Los Angeles County, the PSHB is now established in Ventura, Orange, Riverside, San Bernardino and Santa Barbara Counties. We should be very alarmed at the rate the beetle has spread in southern California! The PSHB bores tunnels, also called galleries, in the xylem of the plant host and compromises the water transportation system. Tissue damage on the plant host is not only caused by the boring action alone, but also by the symbiotic, yet pathogenic, fungi the beetles carry to inoculate the gallery walls and utilize as a food resource. Consequently, the fungal buildup obstructs more water from reaching the branches, which can lead to dieback symptoms and eventually the mortality of the tree. The underlying issue lies in the gradual increase of plant species susceptible to being attacked. Currently, there are over 300 plants, 60 of which the beetle can reproduce on, including several native oaks, maples, sycamores, and willows along with ornamental plants and major agricultural crops (avocado) **(Eskalen et al. 2013)**. A study by **McPherson et al. 2017** showed that 23.2 million trees (32.8%) of southern California’s region are susceptible to attacks by the PSHB beetle. Should half become infested, the approximate cost of removing and replacing those trees will be $15.9 billion with an annual accruement of $616.9 million over the next 10 years. The damage and loss the beetles have already costed the state will only continue to rise without the establishment of an effective management program.

We understand that this pest is a major threat to the forestry and agricultural industry, but what efforts have been made to stop it? So far, conventional methods such as pesticides and mate disruption through pheromone traps have been rendered ineffective due to the beetle’s cryptic lifestyle. The PSHB mates prior to leaving its natal gallery and is only outside for a brief period of time spent entirely on finding a suitable plant host. With that in mind, our laboratory has taken a different course of action that focuses entirely on biological control. Analyses of beetles sampled worldwide paved the path to a foreign exploration trip to Taiwan in the hopes of finding promising natural enemies of the PSBH. Since we are dealing with a wood boring beetle that remains hidden inside of its host, the best approach to encounter any natural enemy is by collecting beetle-infested plant material such as logs. The collection sites can be seen on the map below, all of which were in the district of Tainan City. Infested logs were shipped to the Insectary and Quarantine facility located at the University of California, Riverside (Figure 1A). From there, logs were individually placed in separate containers and monitored daily for anything that emerged (Figure 1B). After three trips and many logs later, we were able to identify three promising parasitoid wasps and two fungal-feeding nematodes associated with the PSHB.

The first parasitoid wasp we have encountered belongs in the family Bethylidae (Figure 2). A closely related species in the same genus has been documented to parasitize the coffee berry borer, another invasive pest with a similar lifestyle to the PSHB. While breaking apart some of the logs, we were able to find parasitized beetles with silk cocoons extending from their heads. Inside one of these cocoons was a bethylid pupa, which looks very promising (Figure 3).

The second parasitoid is a braconid with an interesting method of attack. This novel species in the genus *Sinuatophorus* has prominent and large mandibles to 1) remove any excess material, such as frass and sawdust, at the entrance of the beetle gallery then 2) clasp the head of the beetle and eventually parasitize it (Figure 4). However, most taxonomic descriptions of wasps in this genus always cite Seitner and Notzel's publication from 1925, which mainly focuses on the development and lifecycle of another closely related wasp in a different genus. This poses as a challenge since our understanding of the lifecycle of this novel wasp is limited. Despite this setback, we were able to rear 4 generations by reintroducing every newly emerged wasp to multiple PSHB-infested castor bean logs. Figure 5 illustrates a parasitized beetle with a female braconid wasp that had a molting accident during its development.

The third parasitoid belongs to a very small, yet unique, group. Not only does this wasp attack beetles in their adult stage, but it also lays two eggs: one male and one female. Once fully developed, the female chews a hole from the inside of the abdomen and creates an exit path for herself and the male wasp. Figures 6 and 7 display an image of a female wasp in this group along with the emergence sites from multiple beetle carcusses. But the excitement doesn't stop there! While rearing beetles that emerged from the shipped logs, we were able to come across multiple nematodes. While most of them appeared harmless, some were categorized as fungal feeders. By introducing these fungal-feeding nematodes to beetle galleries, we could potentially use them as an indirect approach to mitigate the population of the beetles by attacking their food supply.

We have come pretty far in the past three years and are now able to narrow our efforts on these natural enemies. Though, as is the case with most biological control programs, there are many challenges and failures that will be faced. Our biggest hurdle to overcome is the cryptic lifestyle of the beetle. Once we introduce newly emerged wasps to beetle-infested logs, any control we have over the rearing process is taken away. Basically, this becomes a black box with no way of observing any parasitization occurring inside without breaking into the logs and jeopardize killing the insects by accident. We are currently trying to improve our rearing methods in the hopes of increasing our wasp colony size. Eventually with large numbers, we can move forward with non-target testing and come to a decision on whether or not we can utilize these natural enemies as a biological control agents to suppress the PSHB population.

Map: collection sites of PSHB beetle-infested avocado logs from Tainan City, Taiwan.

Figure 1A (left): Bag with beetle-infested avocado logs from Taiwan**. Figure 1B (right):** Temperature-controlled room with logs separated in plastic containers in the Insectary and Quarantine facility at UCR.

Figure 2: Image taken of Bethylid adult that emerged from beetle-infested avocado logs collected from Taiwan. Credit: Iris Chien

Figure 3 (left): Parasitized PSHB found with a silk cocoon extended from the head of the beetle. **Right:** A cocoon was dissected, adjacent from the intact cocoon, with a visible bethylid pupa.

Figure 4: **(left)** An image of a female *Sinuatophorus* wasp with the ovipositor unsheathed. **Right:** A closer image of the head and the protruding mandibles. Credit: Iris Chien.

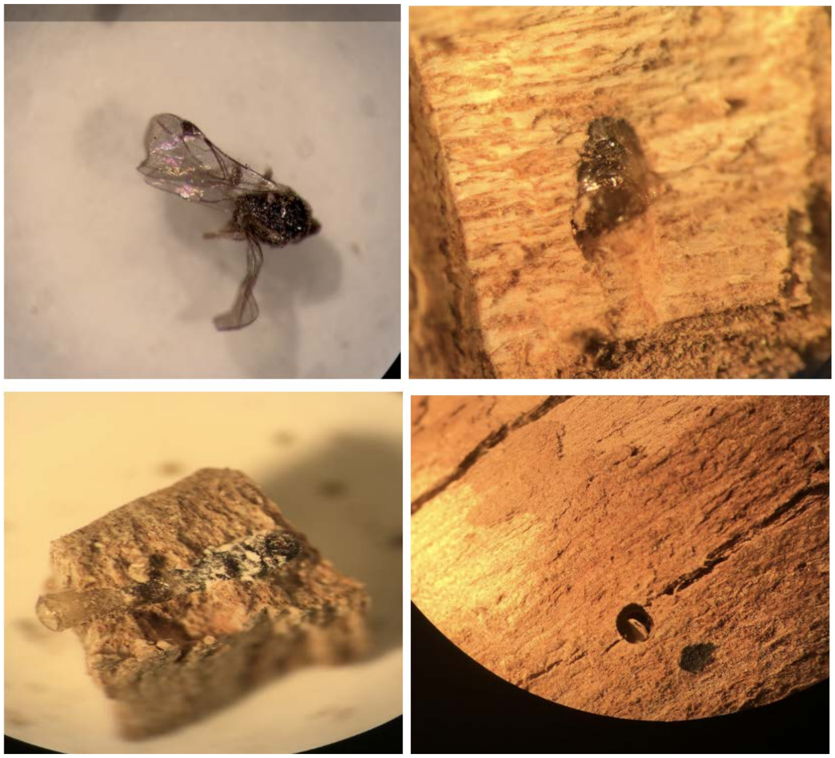

Figure 5: (Top Left) A female *Sinuatophorus* wasp that likely encountered a molting accident. The rest of the images are of the film-like cocoon along with the uncapped opening on the bottom right.

Figure 6 (Left): Female *Phymastichus* wasp.

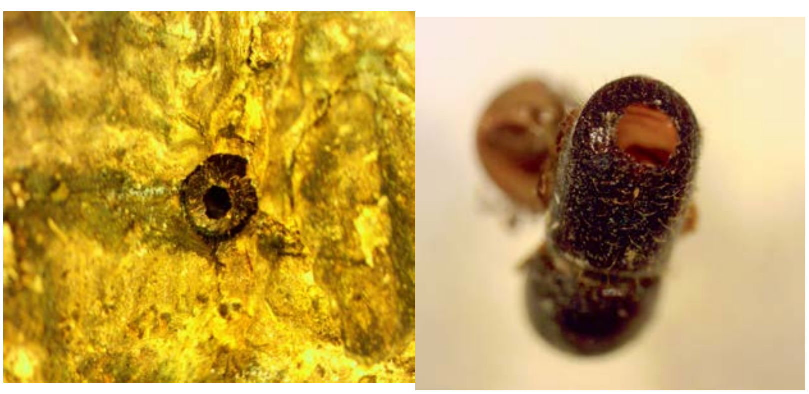

Figure 7: Intact beetle carcass from logs with recorded *Phymastichus sp.* emergence.

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How ants can be "good" in ag production systems

By: Madison Sankovitz, UCR Entomology, Ph.D. Candidate, Purcell Lab

Ants are often underappreciated in the United States for their natural benefits to agriculture. Organized as predatory superorganisms, ants often play an important role in pest management. Further, their influence extends beyond their pest control abilities; many ants live in soil and play a crucial role in maintaining soil fertility. Although recognized for their aphid-protecting tendencies and thus disliked by many growers, many traits of ants make them not only beneficial insects in agricultural settings but possibly a significant solution for sustainable food production moving forward.

Pest Control

The ability of ants to suppress pest species in an efficient way has been known since the year 300 A.D., and farmers continue to conserve and promote ant populations in agricultural systems in many regions of the world (Drummond & Choate 2011). They eat the larvae and eggs of pests and also disturb them during feeding and oviposition (e.g. López & Potter 2000). Weaver ants *Oecophylla* spp. (which live throughout Asia and Australia) are arguably the most well-documented ant genus used in biological control, but similar effects may occur in ants worldwide. Weaver ants share beneficial traits with nearly 13,000 other ant species and are unlikely to be unique in their properties as control agents (Offenberg 2015). For example, all ants can store protein in the form of trophic eggs and brood that can be cannibalized (Nonacs 1991), making their colonies stable and predictable service. Similar social and morphological traits in other ant species suggest great potential for the use of native California ants in the control of arthropod pests, weeds, and plant diseases in orchards and arable crops.

Soil Influences

In addition to pest control, ants are important soil agents in agricultural systems because they contribute to aeration and fertilization, leading to higher soil quality. Aeration is the creation of pockets of air in soil, which help nutrients, water, and fertilizers seep into the soil and reach a greater extent of root systems throughout an agricultural plot. Ants aid in this process by digging a labyrinth of tunnels within the soil. Furthermore, ants introduce outside nutrients (e.g. seeds and insects) to the aerated soil through their foraging; food sources brought into the nest by worker ants decay and fertilize the surrounding plants, especially in no-till plots (Lange et al. 2008). For example, one field experiment showed that ants and termites increase wheat yield by 36% from increased soil water infiltration due to their tunnels and improved soil nitrogen (Evans et al. 2011). This result suggests that ants and termites have similar functional roles to earthworms (often regarded as the most important agents of soil turnover in many regions of the world). Additionally, they may provide valuable ecosystem services in dryland agriculture, which will become increasingly crucial for agricultural sustainability in arid climates, as is the case in some parts of California (Evans et al. 2011).

Ants as Indicators

The presence of ants alone can be beneficial for growers; **ants have been suggested as effective bioindicators of soil quality**, especially in low-income areas that do not have access to expensive soil monitoring equipment (De Bruyn 1999). Growers are being pressured to rectify the issues of land degradation by reforming their management techniques; however, there are few tools to monitor soil health that can reliably inform farmers of the wholistic state of their soil. If ants could be further investigated as accurate bioindicators, they would be valuable tools for use in agricultural practices worldwide.

Future Directions

Through changes in management practices such as tillage and other manipulations of vegetation and crop structure, beneficial ant populations can be conserved in a variety of agroecosystems. However, there is still much research to be done to determine the extent of agricultural services ants provide. Some ant species succeed in defending specific cropping systems, whereas others are damaging and yet others play dual roles. **A future challenge is to determine positive and negative ant–crop pairs and to develop management practices that facilitate the positives and remove the negatives.** Another possibility for research is to focus on the development of barriers that keep ants in soil and off of crops; this would allow them to carry out their soil services while not tending phloem-feeding insects. Additionally, there is a need for better documentation of ant biodiversity in agricultural soils in many regions of the world, including California. This data will allow for evaluation of ants as bioindicators of soil quality and predictions of the vulnerability of ant species under future changes in land use and climate. If we can better understand species patterns and the multitude of roles ants play in agricultural systems, they can be utilized for more sustainable food production in the future.

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Is Eucalyptus a Safe Material for Mulching Trees?

Ben Faber and James Downer

There is a persistent belief that eucalyptus is a noxious weed that kills surrounding plants by chemically destroying them and preventing their germination and growth. This concept is given free support by the visual impact of a eucalypt forest where there is nothing growing but those darn blue gums. And what would happen if eucalyptus trees were ground up and used as mulch for avocado and citrus trees? Eucalyptus would be fatal as a mulch because it kills surrounding plants. Right? Wrong! Read on!

Photo: K. Wolf

The lethality of eucalyptus is most commonly ascribed to *Eucalyptus globulus* (blue gum) - the most widely planted eucalypt in California. However, there are over 700 species of this Australian perennial (or more depending on what reference is used). It seems that all species are equally equated as pernicious, since growth suppression can be seen in stands of many different species. Just look at Australia where only eucalyptus grows (not true). The extent of the eucalyptus problem including its fire hazard is covered in a California Agriculture article (Wolf and DiTomaso, 2007).

The blue gum was first planted in California in the mid to late 1800s as a potential timber species – railroad ties, housing trusses, box material – and medicines. Plantings went in up and down the state to the point that a driver was never far out of sight of a blue gum on either highways 101 or 99 (Farmer, 2013) – a eucalyptic landscape. But by 1913, the USDA had declared eucalyptus plantings of no value, and plantations were abandoned. But the trees just kept on growing, and in some cases spreading beyond their original plantings, especially as it was recognized as a noble landscape tree and was planted for its ornamental value.

As the tree plantings aged, observations suggested there was no biological diversity in the areas where the trees were. It was thought that there must be some chemical inhibition from the trees, preventing other plants from growing. This chemical inhibition is called allelopathy, which had been shown as the chemical suppression of other plants ascribed to walnuts. In walnuts, a chemical called juglone prevents germination and growth of some other plant species.

Allelopathy refers to the harmful effects or interference of one plant on another plant from the release of biochemicals from plant parts by leaching, root exudation, volatilization, and residue decomposition**.** Allelochemicals are secondary metabolites not required for metabolism (growth and development) of the plant producing them. They are an important plant defense against herbivory (i.e., animals eating plants as their primary food) (Fraenkel 1959), and also potentially against other plants.

Allelopathic suppression is complex and can involve a variety of chemicals, such as phenolics, flavonoids, terpenoids, alkaloids, steroids, amino acids, and with mixtures of different compounds. Furthermore, physiological and environmental stresses, pests, pathogens, solar radiation, herbicides, less than optimal soil mineral content, moisture, and temperature levels can affect allelochemicals production. Different plant parts, including flowers, leaves, leaf litter and leaf mulch, stems, bark, roots, soil, and soil leachates and their derived compounds, can have allelopathic activity that varies over a growing season. Allelopathic chemicals can also persist in soil, affecting both neighboring plants as well as plants that might follow the removal of the allelopathic plant, such as at harvest. These different chemicals in leaves and flowers and plant parts could have a significant effect on any herbivory, too.

A great variety of chemicals have been found in eucalyptus leaves and just the smell of the trees is an indication that there are some strong volatile organic compounds (VOCs) in the trees. Numerous studies found an inhibition that occurs with extracts of eucalyptus (Bais et al., 2003; Halsey, 2004; and many others). Inhibition of test plants has been shown in lab and greenhouse studies. DelMoral (1969) theorized that leachate from rain and fog drip could be the major mechanism by which suppressive chemicals concentrate in soils under blue gums causing inhibition of seedlings. Looking at windbreak plantings near avocado or citrus orchards will also show reductions in fruit tree size near the windbreaks.

Recently a very interesting study by Kristen Nelson (2016) explored the impact of field-collected soils on the germination of native plant species using blue gum leaf extracts. Her conclusion was that blue gum extracts had no effect on germination of the native species studied. In her study, the concentration of the extracts was matched to what would be found normally in a field environment. This calls into question the significance of blue gum allelopathy.

In fact, the allelopathic effect of juglone might be called into question, as well, with the long list of plants that do not show inhibition by walnut (Willis, 2000). The presence of a variety of weeds in walnut orchards attests to the resistance of some plants to juglone. The whole concept of walnut allelopathy is questioned by Chalker-Scott (2019).

So, how does the reference to juglone have any relation to the allelopathic effect of eucalyptus? Juglone is probably the most commonly cited allelopathy example in the literature**.**

So if there is some question of the nature of the complex interactions that might occur in walnut, it certainly needs to be more clearly evaluated in eucalyptus.

There is no doubt that plants interact between their roots. Simard and others (1997) demonstrated some time ago that carbon and other nutrients are transferred between species by mycorrhizal fungi. Legumes fix nitrogen used by grasses. There are chemicals in plants that help support the growth of others, and there is probably a continuous dynamic in the landscape - transitions from one plant species to another based on plant residues. Mycorrhizae may help mediate interactions between plants. There are even seeming connections between trees that we don't know about - https://www.eurekalert.org/pub_releases/2019-07/cp-ats071819.php.

Eucalyptus (Euc) do produce chemicals that must have some adaptive reason, that maybe some other plants might take advantage of. Eucalyptus trees develop rapidly, especially on bare ground after a fire. Their canopy shades other plants and the copious leaf drop causes significant mulching, preventing seed germination of both introduced weeds and those in the seed bank. Euc roots are shallow, extensive and very competitive for water and nutrients. It is an aggressive plant, but not necessarily a poisonous plant. Forests are complex environments and in a comparative study of oak woodland and eucalyptus forest, Sax (2002) found eucalyptus forests to be as diverse as a neighboring oak forest. Forests composed of other tree species can effect surrounding plants, not just eucalyptus forests.

Mulch is essential for the healthy growth of avocado, as well as many other trees species. In trials reported by Downer (2010), any mulch was better for the growth of newly transplanted sycamore trees, and a coarse blue gum mulch helped grow the biggest trees. This was in part through physical weed suppression (not allelopathic) and improved soil water relations. Any mulch whether it was eucalyptus derived or not, helped tree growth. Much of the mulch available to tree growers in Southern California is a mixture of woody materials, and eucalyptus is almost never the sole source. In work done with Avocado, mulches of pure freshly chipped (not composted) eucalyptus supported strong growth and led to reduction in *Phytophthora cinnamomi* the cause of avocado root rot.

So any mulching practice needs to be evaluated carefully. How is it applied? To what depth? Proximity to the tree trunk? What time of year is it applied? There is a whole list of guidelines to follow, but whether eucalyptus is part of the mix or is a single component of the mulch should not be a problem. **Go ahead and use eucalyptus in your mulching program.**

A hiking path is seen in the Mount Sutro Open Space Reserve. California's extended drought, disease and multiple pest infestations have exacerbated the decline in health among many trees within the Reserve. Note eucalyptus trees with copious undergrowth of other species. Photo by Susan Merrell

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Botryosphaeria Gummosis and Dieback of Citrus

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Botryosphaeria dieback or *Botryosphaeria* gummosis (formerly known as Dothiorella gummosis on citrus), is found worldwide on many horticultural and agricultural crops. Multiple species of the fungus can often be found on a tree at any given time. Bot canker has a latent stage where it can exist within a tree for years without showing any symptoms. Most species are opportunistic, relying on plants to become stressed before it can infect the tree. The fungus can infect the scion, rootstock, and surface roots of a tree. Disease symptoms include; necrosis of the blossoms, shoots, and fruit. *Botryosphaeria* can lead to wilt, leaf lesions/spots, and fruit rot. Cankers along the stem, twigs, and branches are sunken necrotic (dead) areas with gum exuding from the bark. Transverse section (cross section) exposes wedged or irregular stained sections of infection ranging in color from gray to brown. Infected cambial wood can appear brown to yellowish in color. Extensive dieback, even mortality in extreme cases particularly with younger trees, can occur. Some unique characteristics of *Botryosphaeria* are black pustules (pycnidia – a type of fungal fruiting body) grouped together on the surfaces of or heavily infested bark.

Figure 1. Gummosis on blighted twig – red arrows pointing to gummosis exudates (A). Canker with older exude (B). Blighted foliage and fruit (C). *Botryosphaeria* sp. on fruit (D). Blighted twig (E). Photos courtesy of Ben Faber.

The pathogen favors warm weather from 20°C - 30°C (68°F - 86°F) and rainfall. When, temperatures rise above 10°C (50°F), spores are released to spread the disease in spring. In California, new year's infection typically starts in early April and the middle of spring (late May through June) from previously infected buds, where the disease had not fully developed. Infected buds produce shoots that are infected with the disease. The infected areas can become blighted within three to five days. Symptomatic leaves turn chlorotic (taking on a yellowish and sometimes mottled appearance), wilt, and becomes blighted along with the twig. Flagging (blighted and dead branches) occurs throughout the canopy where the disease has infected.

Figure 2. Flagging in canopy from multiple blighted twigs. Photo courtesy of Ben Faber.

Control and management of the disease depends on cultural practices, chemical control, and integrated disease control management (Michailides & Morgan, 2004). Cultural disease control practices include; pruning, and timing of pruning, avoid pruning or mechanical damage during the rainy season. Prune cankered limbs two to five inches below diseased wood. Remove pruned away dead wood from the field prior to rainy/moist periods. Disinfect pruning tools with quarter strength household bleach – can be corrosive, 100% Lysol, or surface sterilize by flame. Use drip irrigation when possible and avoid wetting the trunk and canopy of trees. When necessary, irrigate with lower pressure to avoid misting and fogging that adds to humidity. Remove weeds to reduce the humidity and habitats for other insect pests. Insects, birds, and irrigation water can aid in disseminating the disease.

Be vigilant in scouting and remove the first sources of inoculation in summertime and repeat until disease is difficult to find. Remove and burn brush from the orchard as the disease can remain viable for as long as three to six years (Michailides & Teviotdale, 2014; Michailides & Morgan, 2004) in woody debris. When possible, protect tress from stressors (water, heat, mechanical injury, salinity, frost, nutrition deficiencies, or sunburn). Soil borne pathogens can predispose plants to *Botryosphaeria* gummosis by disrupting water and nutrient flow. Insect pests (such as scale) can also increase disease incidents as much as 50% or higher.

Integrated pest management is crucial to mitigating this disease. Buy clean nursery stock. Keep active monitoring regimes. Surface disinfect tools and equipment between cuts. Control other diseases (such as soilborn pathogens) and insect pests. Whitewash when necessary. Most importantly, follow proper irrigation and fertilizer regimens to ensure plant health.

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Thysanoptera Californica

An identification and information system to thrips in California

The online Lucid Key, Thrips of California, has been updated. By Mark Hoddle.

This revised version has been produced to overcome technical problems arising from Java software and to incorporate new information and images, together with some additional potentially invasive species.

Information pages are provided to 300 thrips species in 108 genera, with the identification system discriminating 249 species. Of these species, 40 are as yet unrecorded in California but are potential invaders, whether interstate or from overseas.

https://keys.lucidcentral.org/keys/v3/thrips_of_california_2019/

This revised version of Hoddle *et al*. (2012) has been produced partly to overcome technical problems arising from Java software and partly to incorporate new information and images, together with some additional potentially invasive species. Information pages are provided to 300 species in 108 genera, with the identification system discriminating 249 species. Of these species, 40 are as yet unrecorded in California but are potential invaders, whether interstate or from overseas. They have been included for the convenience of quarantine services in USA. In contrast, the Thysanoptera fauna of the American continent north of Mexico has been estimated to comprise 700 described thrips species (Arnett, 1985), with 147 species recorded from Canada (Foottit & Maw, 2019). This identification system is based essentially on adult females, these being the most commonly collected individuals. For larval thrips, the only modern identification system is to part of the Thripidae fauna of Europe (Vierbergen *et al*., 2010).

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Topics in Subtropics