A New and Serious Leafhopper Pest of *Plumeria* in Southern California

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Plumeria, commonly plumeria or sometimes frangipani, are highly esteemed and popular large shrubs or small trees much prized for their showy, colorful, and deliciously fragrant flowers used for landscape ornament and personal adornment as a *lei* (in Hawaii around the neck or head), *hei* (in Tahiti on the head), or attached in the hair. Although closely associated with Hawaii, plumerias are actually native to tropical America but are now intensely cultivated worldwide in tropical and many subtropical regions, where fervent collectors and growers have developed many and diverse cultivars and hybrids, primarily of *P. rubra* and *P. obtusa*.

In southern California because of cold intolerance, plumerias have mostly been the domain of a group of ardent, enthusiastic if not fanatical collectors; however, recently plumerias, mostly *Plumeria rubra*, have gained in popularity among non-collectors, and now even the big box home and garden centers typically offer plants during the summer months. The plants, once relegated to potted specimens that can be moved indoors or under cover during cold weather are now found rather commonly as outdoor landscape shrubs and trees in coastal plains, valleys, and foothills (**Fig. 1**).

Over the last three years, collectors in southern California are reporting and posting on social media about a serious and unusual malady of plumerias, primarily *Plumeria rubra*, where leaves become discolored and deformed (**Fig. 2**). These symptoms have been attributed to excessive rain, wind, and heat potassium or other mineral deficiencies; disease; Eriophyid mites; and improper pH, among others, without any supporting evidence.

We suspect that the actual cause of this serious malady is a leafhopper in the genus *Empoasca*), which we have detected, often in abundance, on numerous, afflicted plumerias (**Figs. 3-4**). This pest is perhaps the greatest calamity to befall plumerias in the history of these plants in California. Here we provide a summary of its history in southern California, symptoms, identification and biology, and possible management strategies.

History

In the summer of 2015 plumeria growers and collectors in the San Diego area first noticed and reported on social media leaf discoloration and deformity on their plants, primarily *Plumeria rubra*. Some even posted photographs of the affected leaves. One collector in the San Diego area might be the first person to have noticed or associated an insect with this malady when

1. Plumerias are now found rather commonly as outdoor landscape shrubs and trees in coastal plains, valleys, and foothills (D. R. Hodel).

2. Plumeria collectors in southern California are reporting a serious and unusual malady of their plants, primarily *Plumeria rubra*, where leaves become discolored and deformed (D. R. Hodel).

3. Co-author Gevork Arakelian sweeps afflicted plumeria plants in Long Beach, where we detected TSL, often in abundance (D. R. Hodel).

4. The leafhopper was always associated with damaged leaves (D. R. Hodel).

she posted a photograph of a leafhopper on an affected leaf in July of 2015. This posting raised little interest.

In the summer of 2016, growers and collectors at multiple locations in southern California were reporting this malady on their plumerias on social media but this time more people were noticing it and more were posting photographs of affected leaves. It seemed that the malady was becoming more severe and widespread.

A year later in the summer of 2017, as reports continued to pour in about this malady, we implemented a survey on social media among plumeria collectors and growers, asking them to provide a location and photographs documenting damage to their plants. Many collectors and growers responded, indicating they their plants were afflicted. This survey information combined with the other numerous reports showed that the malady seemed to have attained epidemic proportions. Collectors and growers from San Diego to Los Angeles were greatly concerned; many had severely affected plants. We then examined afflicted plumerias in numerous sites and always found a small, slender, light green leafhopper associated with damaged leaves (**Fig. 4**). While we knew the genus, *Empoasca*, and suspected the species, *stevensi*, we needed confirmation.

Empoasca is an unusually large and economically important genus of about 400 species (Oman et al. 1990). The species are difficult to distinguish; typically male leafhoppers are necessary for proper identification but they are frequently rare in sampled populations. Eventually, after hours of tedious lab work, we found some males and co-author Gevork Arakelian made the initial identification of *Empoasca stevensi* (Steven's leafhopper). Gevork sent them to leafhopper specialist Alessandra Rung at the California Department of Food and Agriculture in Sacramento, who also tentatively identified them as *E. stevensi*. Young (1953) named and described Steven's leafhopper based on specimens that H. E. Stevens (for whom the species is named) had collected on papaya in Orlando, Florida in March, 1940. If confirmed as Steven's leafhopper, it would be a new record of this pest for California. Rung forwarded the specimens to the Systematic Entomology Laboratory (U.S.D.A.) in Maryland for official identification, a process that could take several months. For the purposes of this article, we will refer to this pest as the "Tentative Steven's Leafhopper" (TSL).

Symptoms

TSL adults and nymphs feed on the abaxial (lower) leaf blade surface, sucking plant juices mostly from the phloem. As they feed, they insert their needle-like stylet and inject substances in their saliva that aid in feeding and perhaps digestion but that are phytotoxic to the plant and cause a suite of symptoms called "hopperburn" and other leaf deformation symptoms. The first symptoms of hopperburn on plumerias are a light, sometimes barely discernable mottling

5. The first symptoms of hopperburn on plumerias are a light, sometimes barely discernable mottling toward the margins of the leaf blade (D. R. Hodel).

6. As symptoms increase in severity, mottling becomes a rather distinct marginal chlorosis (D. R. Hodel).

7. Affected leaves have marginal chlorosis while the center remains green (D. R. Hodel).

8. Eventually the chlorotic areas take on a reddish hue (D. R. Hodel).

9. The marginal chlorosis with a reddish hue contrasts rather strikingly with the green midrib (D. R. Hodel).

10. The colorful marginal chlorosis and the green midrib are rather striking (D. R. Hodel).

toward the margins of the leaf blade (**Fig. 5**), which might be mistaken for a nutrient deficiency or even the beginning of senescence. As symptoms increase in severity, this mottling becomes a rather distinct marginal chlorosis (yellowing) (**Fig. 6**), leaving a green area along the center of the leaf blade (**Fig. 7**). Eventually the chlorotic areas typically take on an orangish, pinkish, reddish, or bronzy hue, which contrasts rather strikingly with the green midrib (**Figs. 8-10**). In some advanced cases the marginal chlorosis become necrosis and the tissue turns brown or black and appears scorched (**Fig. 11**). Lateral veins, especially on the abaxial (lower, underside) blade surface, might turn various shades of pink (**Fig. 12**). Small, white spots composed of the plant's milky sap are typically present along the midrib and lateral veins abaxially and mark leafhopper feeding and or oviposition (egg insertion) wounds (**Fig. 13**).

In addition to hopperburn, leaf deformation characterizes damage from TSLs. Leaf tissue between the lateral veins frequently becomes puckered, giving the leaf blade a corrugated appearance (**Fig. 14**), while the leaf tip curves strongly downward like a sickle or bird's beak (**Figs. 15-17**). At this point the blade is not flat and has narrowed because the two margins have been "pulled" downward, many people referring to the blade as being "cupped downward" although it can also appears somewhat shriveled. In some cases, though, the leaf blade margins are actually pulled upwards. The puckered leaf and downward curved or hooked leaf blade tip can appear on unusually young leaves, even those about 10 cm long and just developing or emerging from the meristem (**Fig. 18**).

Affected leaves senesce prematurely. Effective photosynthetic leaf area in the canopy decreases because of premature leaf senescence and the narrowed, cupped, deformed, shriveled, much reduced leaf blades (**Fig. 19**). Thus, photosynthesis is reduced and growth, including stem, leaf, and flower production, declines. Inflorescences, which normally produce flowers throughout the growing season once they emerge in late spring or summer, cease to produce flowers or do so at a much reduced rate (**Fig. 20**). Secretions of white, milky sap are typically present on the inflorescence rachis and rachillae, marking leafhopper feeding wounds.

So far, over the three years that this pest has been observed in southern California, plants appear to be able to survive this level of leafhopper activity. However, the long-term, multi-year, accumulative effect of these or even more severe infestations is unknown (**Figs. 21-22**).

Symptoms and severity can vary somewhat by cultivar. Little damage has been reported or observed on *Plumeria obtusa* (Singapore plumeria) although this condition might be more apparent than real because this species is much less common in southern California than *P. rubra*. However *P. obtusa* has thicker, harder, more durable leaves than *P. rubra*, which might provide some resistance to the leafhopper. Also, diseases (powdery mildew) and other pests

11. In some advanced cases the marginal chlorosis become necrosis and the tissue turns brown or black and appears scorched (D. R. Hodel).

12. Lateral veins, especially on the abaxial leaf surface, might turn various shades of pink (D. R. Hodel).

13. Small white spots composed of the plant's milky sap are typically present along the midrib and lateral veins abaxially and mark leafhopper feeding and/or egg insertion wounds (D. R. Hodel).

14. Leaf tissue between the lateral veins frequently becomes puckered, giving the leaf blade a corrugated appearance (D. R. Hodel).

15. In advanced cases the leaf tip curves strongly downward like a bird's beak (D. R. Hodel).

16. The strongly downward cupped leaves and a tip like a bird's beak characterize leafhopper damage (D. R. Hodel).

17. TSLs caused this severe leaf damage (D. R. Hodel).

18. The puckered leaf and downward curved or hooked leaf blade tip can appear on unusually young leaves (D. R. Hodel).

19. Effective photosynthetic leaf area in the canopy decreases because of premature leaf senescence and the narrowed, cupped, deformed, shriveled, much reduced leaf blades (D. R. Hodel).

20. Flower production is reduced or ceases altogether (D. R. Hodel).

21. The long-term, multi-year, accumulative effect of severe infestations is unknown (D. R. Hodel).

22. All symptoms of TSL damage are visible on these leaves (D. R. Hodel).

(mites) can cause similar symptoms or mask or even enhance hopperburn and leaf deformation.

We have observed that in severe infestations TSLs are typically abundant in all stages from nymphs to adult on abaxial and adaxial (upper) leaf surfaces. However, cast off exoskeletons, indicators of developmental stages, were visible only on the abaxial surface. Sharp shaking of the foliage usually prompts leafhoppers to dart out quickly and then return just as quickly to the safety and harborage of the leaves. On the leaf surface they frequently move sideways with a characteristic, crab-like motion.

Damage symptoms on plumerias from the TSL in California and Steven's leafhopper in Hawaii are identical or similar. Beardsley (1970), who first reported Steven's leafhopper in Hawaii on plumeria on the University of Hawaii Campus at Manoa (Honolulu), noted that it caused hopperburn and complete defoliation. Later Mau and Kessing (2007) reported that it attacks avocado, papaya, and plumeria; indeed, they considered plumeria the preferred host of Steven's leafhopper and noted that it causes hopperburn, leaf wrinkling, and premature defoliation. However, this type of damage on plumerias in Hawaii, while the same or nearly so to damage in California, apparently was or is never as severe or as widespread as it now is in southern California.

The primary concern of Steven's leafhopper in Hawaii has been on papaya, where it causes symptoms similar to those on plumerias, including typical hopperburn, leaf wrinkling and cupping, and plant stunting (Ebesu 1985, 2004; Mau and Kessing 2007) but, perhaps more importantly, has the potential, like most other leafhoppers, to vector pathogens that cause diseases. Steven's leafhopper is a known transmitter of bunchy top disease of papaya in the Caribbean region (Haque and Parasram 1973). Fortunately, tests of symptomatic plumeria leaves heavily infested with TSLs in southern California were negative for diseases.

Identification and Biology

Because we do not yet have confirmation of the identity of the TSL from the U.S.D.A laboratory, we are unable to discuss in detail its identification and biology. However, we can note briefly some general features that are characteristic of *Empoasca* leafhoppers.

Adult female leafhoppers insert eggs into the veins on the abaxial leaf surface, mostly in transparent, developing and young, fully expanded leaves. Eggs hatch in one to two weeks and five nymphal stages are typical.

Leafhopper nymphs are translucent while second-stage nymphs are light green. Wing pads first develop in third-stage nymphs. Fourth- and fifth-stage nymphs are similar in appearance but

23. Adult TSLs (female top, male bottom) are 2.8 to 3.2 mm long and yellowish green (G. Arakelian).

darken slightly in color and have longer wing pads. Nymphs generally remain on the leaf from which they emerged.

Adult TSLs are 2.8 to 3.2 mm long. Adults are light yellowish green with two, white longitudinal bands on the back (**Fig. 23**). The transparent wings take on an orange hue when folded over the abdomen.

Management

Practice exclusion. When obtaining new plants, always inspect them carefully for pests and diseases and reject those that are infected or infested; this strategy applies to any disease or pest. If even slight leafhopper burn symptoms are present but TSL is not, consider rejecting them because the leaves might still harbor eggs that can hatch and spread the pest to new plants; as an alternative, manually defoliate the plant, bag the leaves securely, and dispose of the bags in the trash.

Known natural enemies of leafhoppers in general include spiders, parasitic wasps, lady bugs, lace wings, and pirate bugs, and these should be encouraged wherever possible.

Leafhopper damage symptoms on papaya were more serious under dry conditions (Constantinides and McHugh 2008); thus, avoiding drought stress might be helpful. Periodic hosing off of foliage might dislodge nymphs and remove dust that can lessen the efficacy of natural predators. However, avoid wetting plumeria leaves in late afternoon or early evening, especially in more humid coastal areas, because this practice might facilitate disease development.

Because TSLs deposit eggs within the leaves, cleaning up leaf litter and defoliating plants might help reduce populations. Regularly rake up fallen leaves, bag the leaves securely, and properly dispose of the bags in the trash. Complete manual defoliation of leaves remaining after winter and just before active growth resumes in the late spring and raking up, securely bagging, and properly disposing of these leaves might reduce leafhopper populations for the upcoming growing season. However, the effectiveness of defoliation and raking up of fallen leaves in reducing leafhopper populations might be somewhat limited and might only catch a few late-hatching larvae because leafhoppers deposit eggs in very new or young leaves and the eggs hatch within 14 days. Removing and disposing of older leaves, which typically are the ones that have fallen and/or would be removed by manual defoliation, likely would not greatly interrupt the leafhopper life cycle. Leaf removal by itself, though, would remove sources of food and harborage and would likely reduce leafhopper numbers, especially is employed with judicious use of pesticides. To reduce leafhopper eggs and some early larval stages, very young leaves would need to be removed.

In general leafhoppers appear unusually sensitive to many pesticides but, unfortunately, not to the safer, least toxic materials. Nonetheless, always start with the least toxic materials first and, if these are ineffective, then consider more toxic compounds. If populations are severe or in some instances as a prophylactic measure, soil/root zone applications of systemic imidacloprid for long-term control and foliar sprays of non-systemic bifenthrin for immediate knockdown will likely be effective. Remember, though, that these materials have been linked (correctly or incorrectly) to bee decline or are highly toxic to bees; fortunately, bees do not visit plumeria flowers. Nonetheless, consider the damage that pesticides can do to the environment, and make an informed, educated decision about their use.

Use of yellow sticky cards and vigilant, judicious scouting to determine and monitor leafhopper populations will help in selecting and implementing an appropriate management strategy.

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Literature Cited

Beardsley, J. W. 1970. Notes and exhibitions. *Empoasca* spp. Proc. Hawaiian Ent. Soc. 20: 484, 487.

Constantinides, L. N. and J. J. McHugh, Jr. (Eds.). 2008. Pest Management Strategic Plan for Papaya Production in Hawaii. Workshop Summary, Komohana Research and Extension Center, University of Hawaii at Manoa, Hilo, HI, 2 December 2005. On-line: *https://ipmdata.ipmcenters.org/documents/pmsps/HIPapayaPMSP.pdf*

Ebesu, R. H. 1985. The Biology of the Leafhopper *Empoasca stevensi* Young (Homoptera: Cicadellidae) and its Toxicity to Papaya. MS. Thesis. University of Hawaii, Department of Entomolgy, Honolulu.

Ebesu, R. H. 2004. Hopperburn in Hawaii Caused by Steven's Leafhopper. CTAHR Pub. IP-15. University of Hawaii, Honolulu. On-line: *https://www.ctahr.hawaii.edu/oc/freepubs/pdf/ip-15.pdf*

Haque, S. Q. and S. Parasram. 1973. *Empoasca stevensi*, a new vector of bunchy top disease of papaya. Plant Dis. Rep. 57(5): 412-413.

Mau, R. F. L. and J. L. M. Kessing. 2007. *Empoasca stevensi* (Young). Crop Knowledge Master. On-line: *http://www.extento.hawaii.edu/kbase/crop/type/e_steven.htm*

Oman, P. W., W. J. Knight, and M. W. Nielson. 1990. Leafhoppers (Cicadellidae): A Bibliography, Generic Checklist and Index to the World Literature 1956-1985. CAB Interntional Institute of Entomology. Wallingford, United Kingdom.

Young, D. A. 1953. Empoascan leafhoppers of the Solana Group with descriptions of two new species. J. Agric. Univ. Puerto Rico 17(2): 151-160.

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