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A CLOSER LOOK AT IPM

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Fork-tailed Bush Katydid Fruit Scarring in Clementine Mandarins

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Project Summary

Fork-tailed bush katydids are a serious fruit-feeding pest of sweet oranges, chewing deep holes in the young fruit after petal fall. Their feeding damage leaves round, scabby scars that persist to harvest. In contrast, fork-tailed bush katydids are not considered economic pests in 'Tango' and 'W. Murcott' mandarins because they do not readily feed on the fruit. We determined the status of fork-tailed bush katydids in clementine mandarins, using a combination of traditional field experiments and analyses of grower and pest control advisor (PCA) data collected from 201 commercial groves in the San Joaquin Valley. Like sweet oranges, katydid nymphs are present in commercial groves and feed readily on the young fruit of the four common clementine cultivars we tested. However, the feeding damage develops into jagged, irregular and sometimes webbed scars on mature clementines, more similar in appearance to caterpillar damage in oranges, but not the characteristic round katydid scars seen in oranges. The katydid-scarred clementine fruit also frequently split and abscise[1] late in the season, creating additional economic losses. We are updating the UC IPM Pest Management Guidelines for Citrus to include specific guidelines for mandarins that reflect this new information – that fork-tailed bush katydids are clearly a fruit-eating pest in clementines, causing scarring with a previously unrecognized appearance.

Do Katydids Damage Clementines?

Citrus fruit with visible imperfections in the rind are consistently rejected by consumers, meaning that scarred fruit are downgraded to 'choice' or 'juice' at the packing house for a net loss of value. Insect pests that directly feed on young citrus fruit are, therefore, among the most concerning for citrus growers in California's fresh market industry. Fork-tailed bush katydids (*Scudderia furcata*) are one of these serious early-season pests of sweet oranges (*Citrus sinensis*), with the voracious nymphs feeding directly on young fruit after petal fall, creating characteristic round, scabby scars that persist to harvest. In contrast to sweet oranges, the most commonly grown cultivars of "true" mandarins (*C. reticulata*), 'Tango' and 'W. Murcott Afourer,' are resistant to fruit damage by fork-tailed bush katydids. The nymphs may be present in the groves of these mandarins, but reject opportunities to feed on the young fruit, at most causing very minor, shallow indentations in the fruit surface that are imperceptible at harvest compared to other minor mechanical damage incurred throughout the season. Clementines represent a third citrus species, *C. clementina*, that recently has increased in popularity to rank as the third most common citrus group grown in the Central Valley (CDFA & CASS 2018). The goal of this research was to determine the status of fork-tailed bush katydids in clementines.

Analyses with "Big Data" and Field Experiments

As part of our broader project to develop ecoinformatics[2] methods for pest management in California citrus, we have constructed a large "*Citrusformatics*" database of pest management records contributed from growers and PCAs in Tulare and Fresno counties. We analyzed a subset of this database covering 201 commercial groves each sampled for one to ten years for katydid densities and damage in sweet oranges and clementines, controlling for effects of other variables such as crop year and grove size. The field scouting reports indicated that the incidence of katydid nymphs in the weeks after petal fall is similar in commercial sweet orange and clementine groves. However, the scarring attributed to katydids in surveys of fruit in harvest bins was relatively low in clementines. Scarring attributed to cutworms, by contrast, was higher than expected in clementines, as cutworm densities were generally very low.

These database analyses demonstrate that katydid nymphs are present in clementine groves, but there were several possible explanations for the low reported scarring, which we needed to test experimentally. We conducted two

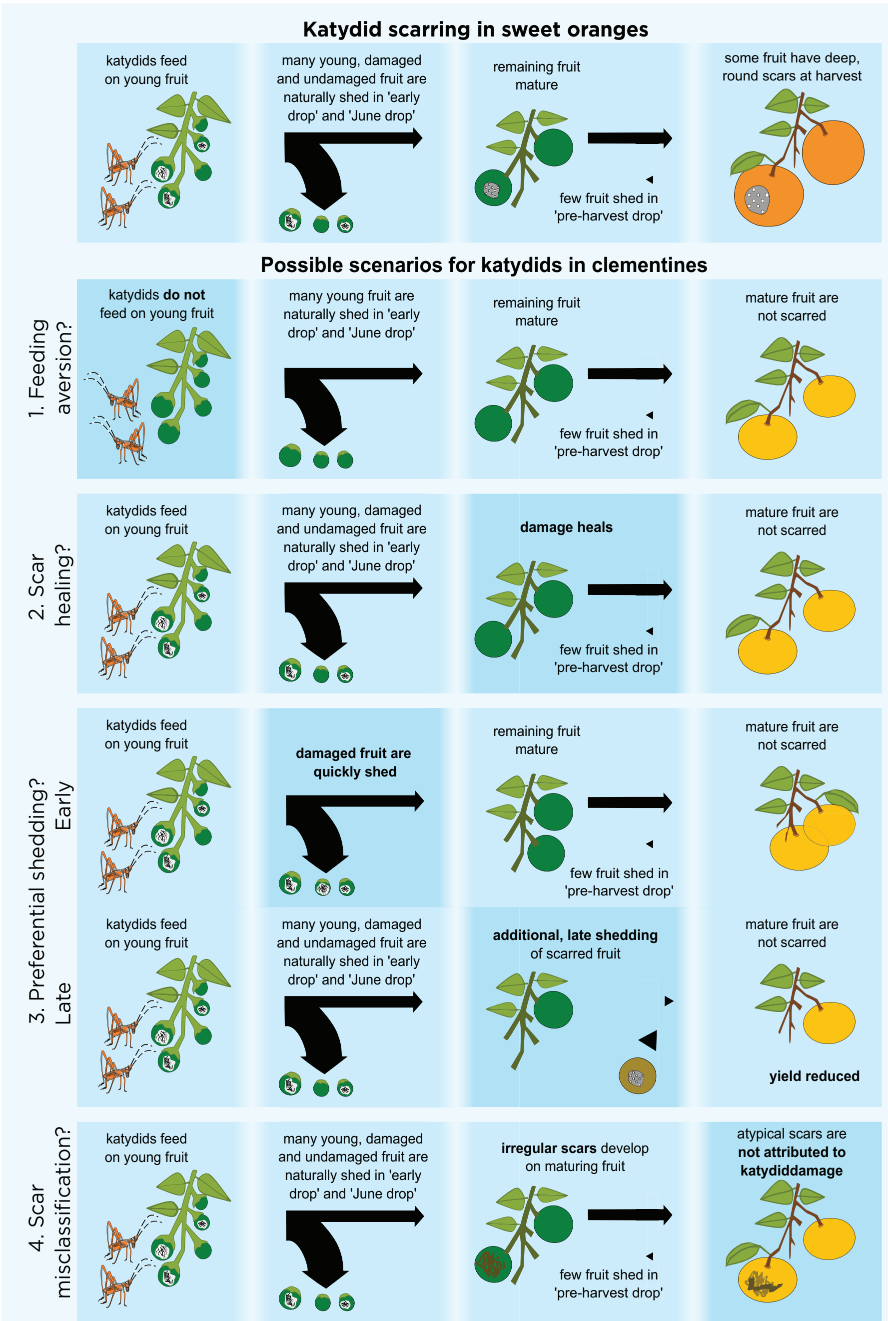

Figure 1. Possible scenarios of katydid scarring in clementines: Four hypotheses were experimentally tested as possible explanations for the observational results obtained from database analyses.

complementary experiments during the 2018-19 season in a mixed block of clementines at the Lindcove Research and Extension Center, using cultivars 'Clemenules,' 'Corsica 1,' 'Fina' and 'Fina Sodea.' In the first experiment, katydid nymphs were caged onto terminal branches bearing young fruit for seven days, after which they were removed and the feeding damage on each fruit was assessed. In the second experiment, artificial rind damage was mechanically applied to young fruit to mimic katydid feeding, but in a standardized way. Each fruit was tagged and monitored until it abscised or matured to harvest.

Together, these experiments tested four hypotheses to explain the lower than expected katydid scarring in commercial clementines:

1. feeding aversion: katydids are present in the groves but not feeding on young clementines;
2. scar healing: damaged clementines recover during development;
3. preferential shedding: clementines damaged by katydid feeding preferentially abscise; and
4. scar misclassification: katydid scars on clementines have a novel, undocumented appearance, different from that observed on sweet oranges that could cause misclassification of scarring in harvest bin surveys (**Figure 1**).

In the case of the third hypothesis, the timing of preferential abscission also is important. If the damaged fruit are shed during the "June drop" as part of the overall proportion of fruit already set to shed, the tree is essentially taking care of the damage, whereas fruit shed later in the season already have taken resources from the tree to mature thereby reducing yield.

Katydids Leave Jagged, Irregular Scars on Young Clementines

We found strong support for hypotheses 3 and 4. We did not find support for hypotheses 1 or 2. The katydids fed heavily on many of the young clementine fruit of all four cultivars tested (**Figure 2A**). The feeding damage ranged from small, shallow cuts (**Figure 2B**) to multiple overlapping bites creating contiguous areas of superficial damage (**Figure**

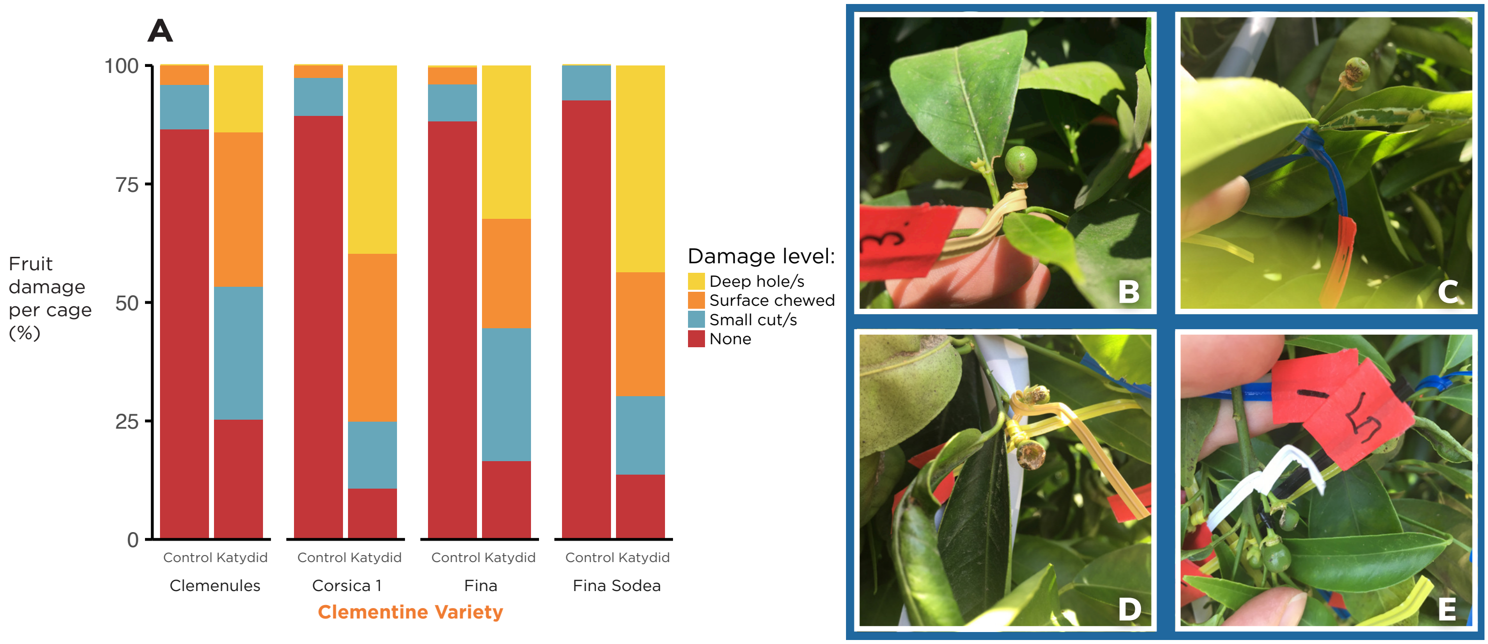

Figure 2. Katydids fed heavily on many of the young fruit of all four common clementine cultivars tested. The bar graph (A) indicates the mean percentage of fruit per cage with each damage type upon removal of the katydids. The feeding damage ranged from small, shallow cuts (B); to areas of superficial damage (C); to deep holes (D) or fruit chewed off at the base (E). The low levels of damage in the control cages were likely mechanical damage from wind or minor preexisting feeding damage from before the cages were applied.

Figure 3. The feeding damage developed into irregular scars (A) and the near-mature fruit sometimes split along the scar lines (B). At harvest, the fruit retained from katydid treatment cages had highly variable scars, including large, deep, scabby, and irregular or webbed scars (C-E), smaller (F) and thinner (G) scars. An example of a circular scar typical of katydid damage in sweet oranges is provided for comparison (H).

Fork-tailed bush katydid.

2C) to deep holes (**Figure 2D**). In some cases, the fruit were chewed off at the base or completely consumed down to the floral disc (**Figure 2E**).

Maturing fruit did not recover from the damage. They developed substantial scarring where the katydids had fed, in many cases leaving long, irregular, or jagged scars (**Figure 3A**). Fruit damaged by katydids were more likely overall to abscise than undamaged fruit, with abscission of heavily damaged fruit occurring throughout the season, but especially late in the season from August onward. At the monitoring timepoint in October, we noticed that several of these nearly mature fruit had split along the katydid scars (**Figure 3B**), which likely contributed to the late abscission. At harvest, the retained fruit from katydid treatment cages had a range of scar morphologies. In some cases, the scars were large, deep, scabby and irregular or webbed in shape (**Figure 3C-E**). Other scars were smaller (**Figure 3F**) or thinner (**Figure 3G**). An example of a circular scar typical of katydid damage in sweet oranges is included for comparison (**Figure 3H**). Fruit that were mechanically damaged with a standardized, circular hole developed round scars and were not more likely to abscise than undamaged controls, indicating that the katydid feeding interacting with the fruit growth caused the unexpected scar appearance and increased fruit abscission.

Building a Profile of Katydids in California Citrus

These results provide a two-fold explanation for the lower-than-expected katydid scarring of clementines in commercial harvest bins:

1. katydid-damaged clementine fruit often are shed from the tree late in the season, meaning fewer scarred fruit make it into harvest bins, and

2. katydid scarring in clementines looks more like caterpillar damage in oranges than katydid damage in oranges, leading to an underestimation of katydid scarring and an over-estimation of caterpillar scarring in commercial clementine harvests.

The effect of the increase of pre-harvest fruit drop is somewhat difficult to assess. This abscission does save the cost of harvesting fruit destined for downgrading, but reduces yield, as the tree already has invested resources maturing the damaged fruit.

For growers, this means there is a need to monitor and control katydids on clementines. Growers also need to update the interpretation of damage found at harvest in bin samples for clementines to a search image of jagged and irregular scars of a range of shapes, rather than just round scars. Control methods for caterpillars and katydids are quite different, making it important to distinguish between these two early-season insect pests. We tested only four of the most commonly grown cultivars of clementines ('Clemenules,' 'Corsica 1,' 'Fina,' and 'Fina Sodea'), but the results may extend to other cultivars in the species *C. clementina*.

Combining these findings with our earlier studies reveals three very different pest profiles of katydids in the three common citrus species considered. Fork-tailed bush katydids are notorious pests in sweet oranges, where their feeding generates deep, round scars. This project has demonstrated that these katydids also are clearly fruit-feeding pests in clementines, where they cause irregular scars and fruit drop. In contrast, katydids are not pests in 'Tango' and 'W. Murcott Afourer' mandarins, where they rarely feed on the fruit.

Establishing IPM Guidelines for Mandarins

This project has been part of a larger effort to revise the citrus IPM guidelines to include information specific to California mandarins. We chose to focus this report on these recent findings concerning katydids in clementines due to their immediate implications for katydid management and to refer the reader to previous reports about the *Citrusformatics* database (Cass et al. 2018, Cass et al. 2019, Cass et al. 2020), katydids in 'true' mandarins (Cass et al. 2019a,b) and citrus thrips in multiple mandarin species (Mueller et al. 2019). We now are in the process of updating the UC IPM Guidelines for Citrus to include specific sections on katydids and citrus thrips in mandarins and clementines (Grafton-Cardwell et al. 2020), updating the UCANR katydid online course (*https://campus.extension.org/course/index.php?categoryid=142*) and producing a Photographic Guide to Early Season Fruit Scarring in Sweet Orange and Mandarins to complement UCANR Publication 8090 (Grafton-Cardwell et al. 2003).
We thank all the growers and PCAs who have supported this research and contributed data to the *"Citrusformatics"* database. While the current projects conclude, the database continues to grow, serving as a resource to address future challenges in citrus. Our experimental research continues with a focus on determining the status of European earwigs as fruit-feeding pests in oranges and mandarins, supported by CRB Research Project #5500-220.

Glossary

[1]**Abscission:** The shedding or dropping of leaves, fruit, flowers or seeds in the case of plants.

[2]**Ecoinformatics:** A research data mining method to collect and analyze a large volume of data pooled from multiple sources, often covering a larger scale and timeframe relative to traditional field experiments.

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