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New Faces at the CRB's Helm

A fork-tailed bush katydid nymph.

Resistance of 'Tango' Mandarins to Fork-tailed Bush Katydids

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Project Summary

The current integrated pest management (IPM) guidelines for key California citrus insect pests are based on research done on oranges. We are using a combination of "big data" analyses and field experiments to help create specific recommendations for the mandarin cultivars now being grown. We previously reported results from analyses of a database of pest control advisor (PCA) and grower records of citrus grove management in the San Joaquin Valley showing very low fruit scarring by fork-tailed bush katydids in 'Tango' and 'W. Murcott' mandarins, despite similar densities of these insects in mandarin and orange groves after petal fall. Presented in the following article are results from field experiments to test hypotheses regarding the mechanisms underlying this observation. We found that katydids reject opportunities to feed on 'Tango' fruit. Instead of chewing deep holes in the fruit, as was commonly observed for oranges, the katydids only scratched the surface of the 'Tango' fruit. At harvest, the superficial scratches on the 'Tangos' were not easily distinguishable from other minor damage. This indicates that in contrast to sweet oranges, 'Tango' mandarins have natural resistance to fork-tailed bush katydids, making them a non-pest in this crop. Preliminary analyses of ongoing experiments indicate that these results extend to 'W. Murcott' mandarins, but not to Clementines.

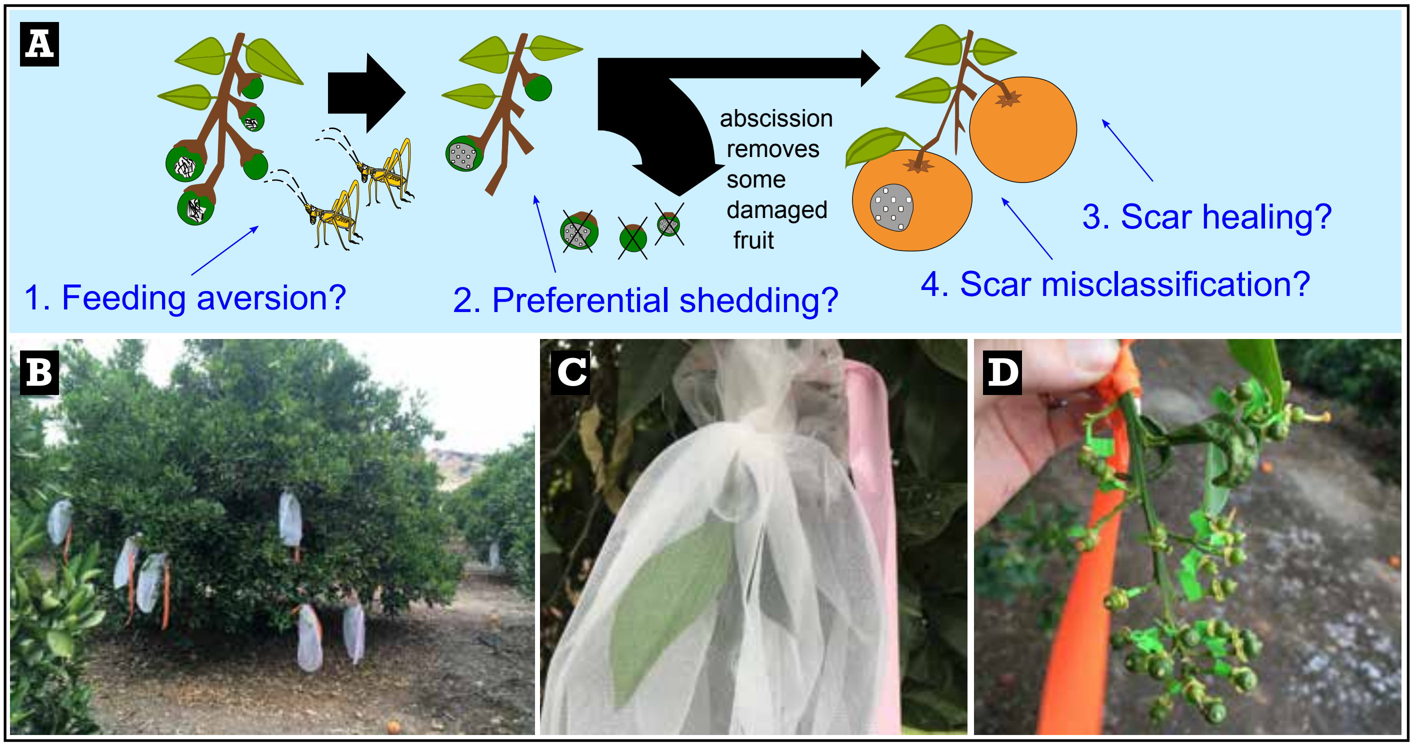

Figure 1. Experimental setup: (a) four hypotheses were tested as possible explanations for the database observations, (b) katydids were caged on branches of an experimental tree for five days, (c) the caged katydids had access to fruit and leaves, (d) after the cages were removed, the fruit were inspected for feeding damage and tagged to track their retention/shedding and the development of any scarring.

Katydids are Early-season Pests in Oranges. What about Mandarins?

Fork-tailed bush katydids (*Scudderia furcata*) are known to be early season pests of California sweet oranges. The nymphs feed directly on young fruit, creating scars that persist to harvest and often cause the fruit to be downgraded from "fancy" or "choice" to "juice" quality, resulting in a nearly complete loss of value (Grafton-Cardwell et al. 2003). Katydid nymphs are mobile and can damage many fruit in a short amount of time. Therefore, one katydid find in a three-minute search triggers an insecticide application (Grafton-Cardwell et al. 2017). Grower understanding of this serious pest is based on years of experience and knowledge gathered in sweet oranges. However, California citrus production has changed substantially in recent years, with a sharp increase in mandarin acreage (CDFA-CASS 2018). Research is needed to understand the biology of insect pests in mandarins and to optimize guidelines for effective pest management.

We previously reported results emerging from a large "*Citrusformatics*" database of management records from growers and PCAs in Tulare and Fresno counties, indicating that similar densities of katydid nymphs are found in commercial 'Tango' and 'W. Murcott' mandarin and sweet orange groves after petal fall. Despite these similar densities, however, almost no katydid scarring is recorded in 'Tango' and 'W. Murcott' mandarins in surveys of harvest bins (Cass et al. 2018; Cass et al. 2019b). These observations raised the question of whether fork-tailed bush katydids should be considered economic pests in these mandarin cultivars.

Testing Hypotheses Arising from Grower and PCA Data

We conducted a series of field experiments to test four possible explanations for why katydid scarring is lower in mandarins than in sweet oranges, despite similar katydid field densities:

1. a feeding aversion by the katydids to mandarin fruit,
2. preferential shedding of damaged fruit by mandarins,
3. healing of the feeding-damaged mandarins and
4. different scar appearance on mandarins, causing misclassification of the damage at harvest.

It was important to test these hypotheses in replicated field experiments, because they have different management implications (Cass et al. 2019a).

We collected katydid nymphs (approximately 2nd instar; E.E. Grafton-Cardwell Extension Online Campus Course) and caged them onto terminal branches of 'Parent Washington Navel' sweet navel orange trees and 'Tango' mandarin trees at the Lindcove Research and Extension Center at two different times soon after petal fall. After five days, the katydids were removed and the feeding damage on fruit and leaves was examined. Each fruit was tagged and monitored through harvest for fruit shedding and scar development (**Figure 1**).

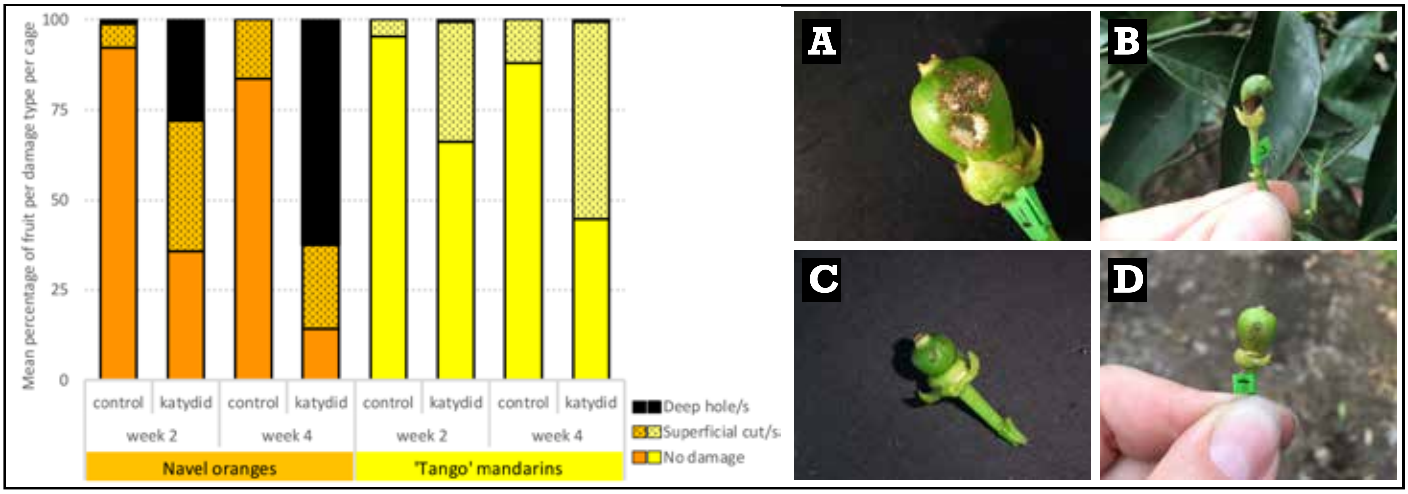

Figure 2. The katydids fed readily on sweet oranges, chewing deep holes in the fruit; but on 'Tango' mandarins, they almost exclusively caused superficial cuts or surface scratching. Graph indicates the mean percentage of fruit per cage with each damage type upon removal of the katydids. A and B: examples of deep holes chewed in oranges. C and D: examples of superficial cuts in mandarins.

Katydids Don't Feed on 'Tangos'

We found strong support for the first hypothesis of feeding aversion. The katydids fed readily on the sweet oranges, chewing deep holes in the fruit; but on 'Tango' mandarins, they almost exclusively caused only superficial cuts and occasionally some superficial chewing in the later experiment when they were larger (**Figure 2**). We interpret the chevron-shaped cuts seen on some fruit as the marks left when the katydid's paired mouthparts sliced into the fruit, but the katydid then rejected the fruit upon making an initial tasting bite. In contrast, the deep holes in oranges appear to be the result of many repeated bites and ingestion of the fruit. This provides an explanation for the perplexing observation from grower and PCA-generated data: fork-tailed bush katydids are present in 'Tango' trees, but are not eating the fruit.

The only part of the 'Tango' plant on which the katydids fed were the floral tissues: stigmas, styles and floral discs, all of which become unavailable as the fruit grows. This feeding on flower parts appears to have no economic significance. Leaf feeding observed in the cages was low, even in the oranges (data not shown).

The second hypothesis of preferential shedding of damaged fruit does not appear to contribute substantially to the difference in final scarring rates between oranges and mandarins. The third hypothesis of damage recovery also was not supported by our experiments. For example, when we used a sharp metal punch to create small holes in the rind of young fruit that mimic the holes katydids chew into oranges, the 'Tango' fruit did not heal, and the resulting scars were deep and scabby (**Figure 3a**), similar in appearance to the scars seen from the same simulated damage in navel oranges (**Figure 3b**). Thus, it appears that the absence of such scars

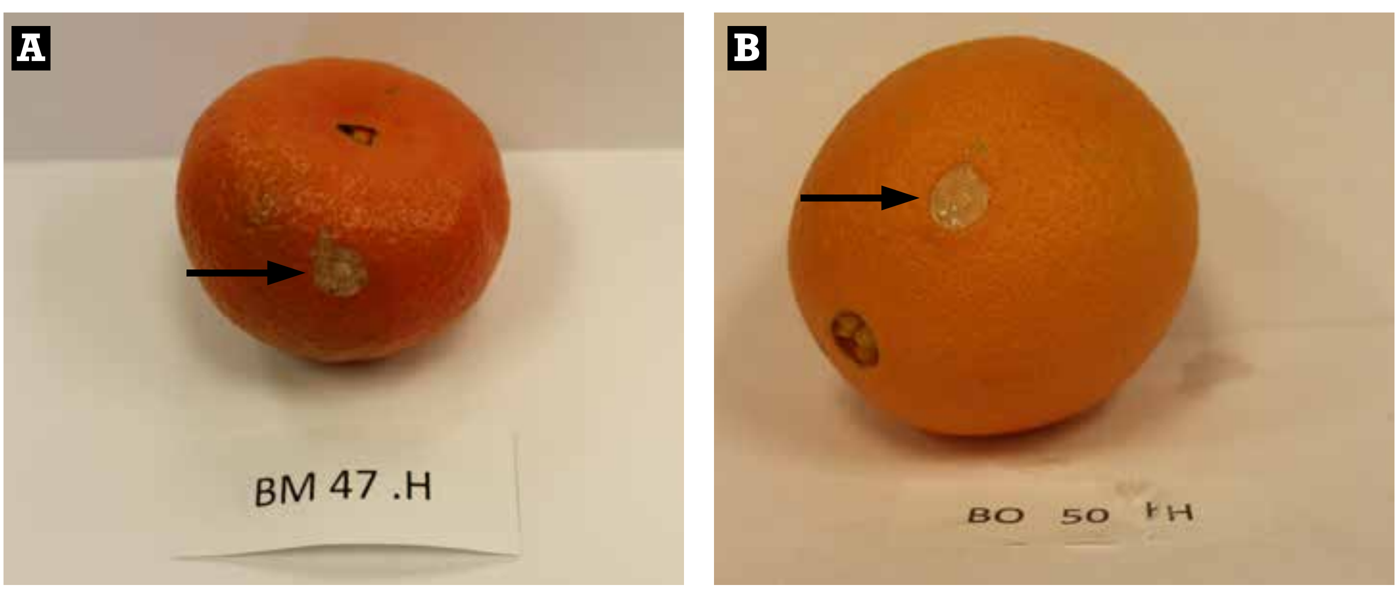

Figure 3. Experimental fruit that had been scraped with a sharp metal punch after petal fall to simulate katydid feeding (a) 'Tango' mandarin, (b) navel orange, showed scarring at harvest (indicated with arrows).

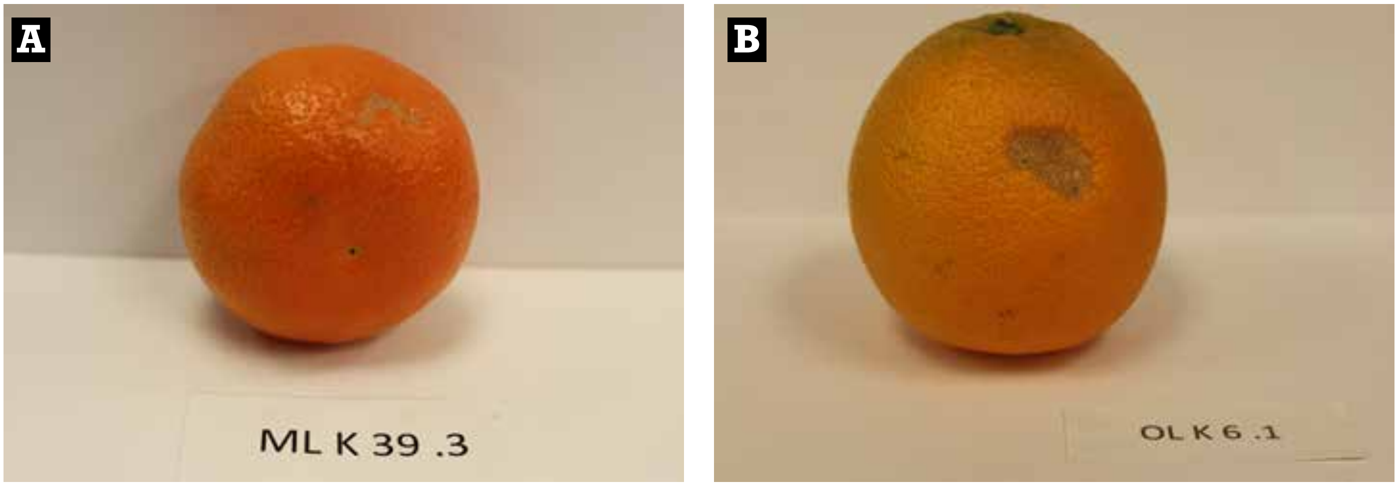

Figure 4. Experimental fruit examined at harvest that had been enclosed with katydids after petal fall. In (a) 'Tango' mandarins, the shallow cuts were difficult to trace, with the mature fruit having no discernable damage or rarely, a shallow scab. In (b) navel oranges, the initial deep chewed holes resulted in deep scars in mature fruit.

on harvested 'Tangos' reflects the refusal of katydids to chew deep holes into the young 'Tango' fruit.

We did observe some small, shallow, irregular-shaped scars in the 'Tango' rind (**Figure 4a**), but could not trace them back to the original katydid damage. In contrast to the large scars seen in navel oranges (**Figure 4b**), these marks were indistinguishable from the other minor damage seen on the initially undamaged control fruit, likely caused by wind or rubbing.

Conclusions

Heavy feeding damage by fork-tailed bush katydids is extremely rare in 'Tango' mandarins, and the rare, heavily damaged fruit often promptly shed. Fork-tailed bush katydids do cause superficial feeding damage, but this damage is unlikely to be of economic consequence at harvest. With the combined support of these experimental results and the previous observational database results covering hundreds of commercial groves and growing conditions, we suggest that 'Tango' and, based on the database analyses, 'W. Murcott' mandarins have innate resistance to fork-tailed bush katydids. Applications of insecticides for katydid control in these cultivars can, therefore, be eliminated in favor of relying on the plant's natural defenses. Similar experiments have been conducted to test these same hypotheses in Clementine cultivars. This ongoing work will be reported separately; but from preliminary analyses, a very different picture is emerging again for fork-tailed bush katydids in Clementines compared to 'Tango' mandarins and sweet oranges.

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