UNIVERSITY OF CALIFORNIA
Agriculture and Natural Resources

Scientific basis for the selection of preharvest insecticides applied for bulk citrus movement in California

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Introduction

The Asian citrus psyllid (ACP) (*Diaphorina citri*), the vector of the devastating bacterial citrus disease huanglongbing (HLB), can be easily spread by movement of citrus from groves to packinghouses. Studies in Florida have shown that ACP can be transported when infested fruit is harvested into bins and transported in open trailers to packinghouses (Halbert et al. 2010). In California, evidence for this method of spread was the appearance in 2015-2017 of psyllids in detection traps along highway corridors in central and northern California, where the psyllid had not yet established (McRoberts and Grafton-Cardwell 2018). Several regulations were put into place to minimize this method of spread. The first was tarping of all trucks transporting citrus fruit, implemented in April 2017. Tarping limited psyllid dispersal along the route to the destination. The second was the creation of 7 zones comprising a 'Bulk Citrus Regional Quarantine' (Fig. 1) and requiring mitigations to be applied if fruit is moved between these zones. Growers are required to sign compliance agreements, submit a ACP-Free Declaration form or HLB Pest Risk Mitigation form to the origin and destination county agricultural commissioners' offices, utilize tarping, and deliver fruit and forms to a Program-approved packing house or processor. These steps ensure that psyllids and the bacterium are not spread through fruit transport to packing houses.

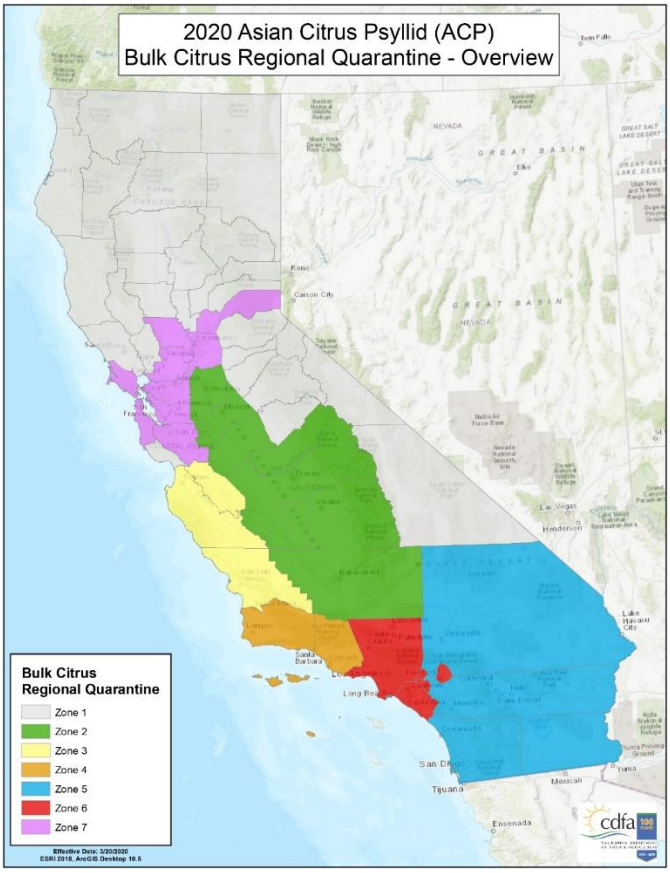

Fig. 1 Bulk Citrus Regional Quarantine

Mitigations required to move bulk citrus around California

The purpose of the mitigations is to minimize the risks: (1) that there are adult psyllids in the bins of fruit that might be transported and establish in un-infested areas of California or; (2) carrying the bacterium that causes HLB to new areas. Washing the fruit in a packing house or on a portable washing line close to the location of harvest is the best method to disinfest citrus of psyllids. Walse et al. (2014) demonstrated in a packing house situation that each component of that line (dunking, soaking, brushing and rolling) is very effective for removal of psyllid adults (99% removal) and when combined provide complete removal. However, not all growers have access to a packing house near their orchard and washing can predispose the fruit to greater infection from post-harvest pathogens such as molds. Growers were concerned that washing the fruit then shipping it to a packing house where it would be washed again would affect fruit quality. Therefore, there was a desire for an alternative mitigation to post-harvest washing.

The mechanical alternatives to washing that were developed were field 'cleaning' or disinfesting the harvested fruit using mechanical equipment or by rolling the fruit by hand across a grate into the bins. These activities, when carried out correctly, remove leaves, twigs and dislodge adult psyllids. Mechanical methods of disinfestation can be used by organic growers. A chemical alternative to washing or cleaning is to spray the orchard with an insecticide to kill the psyllids just before harvest. The majority of growers opt for this 'spray and move' option (Fig. 2) because it is the most economical and results in the least risk of damage to the fruit. This option is currently not available for organic growers, because organic pesticides do not have the residual activity needed to guarantee that fruit will stay un-infested in the interval between treatment and harvest.

Zone 6 has special circumstances because HLB infected citrus trees have been found in this region. Fruit leaving this zone must be washed or have two of the above described mitigations completed to prevent spread of the bacterium prior to shipment out of that zone.

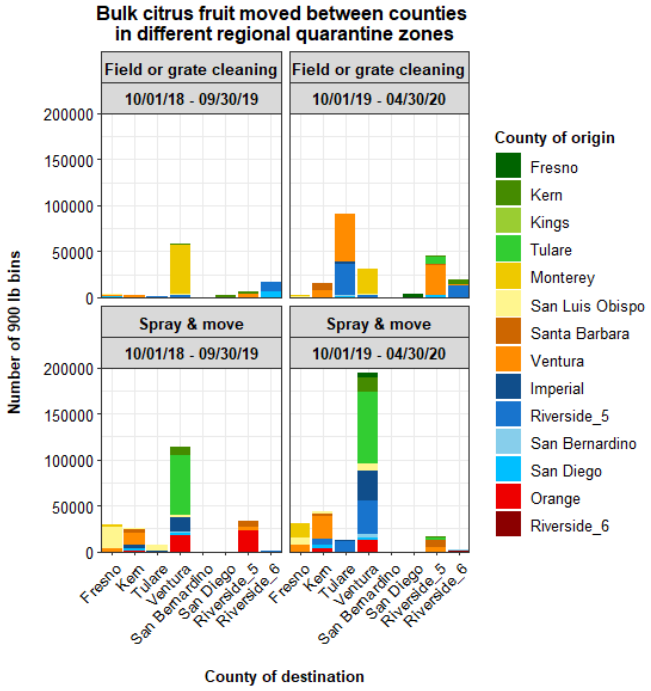

Fig. 2 Number of 900 lb bins of citrus fruit moved between counties in different bulk citrus regional quarantine zones during the 2019 fiscal year and part of the 2020 fiscal year, by cleaning method. Information provided by CDFA.

Insecticides for the Spray and Move Program

For the spray and move option, a preharvest foliar insecticide is applied within 14 days prior to harvest. Thus, insecticides used for this purpose must have a high level of efficacy and at least a 14 day residual life. Both conventional and organic insecticides have been extensively studied in the laboratory, greenhouse and field to determine their efficacy against ACP (Bethke et al. 2014, 2015, 2017; Qureshi et al. 2014; Tofansazi et al. 2016, 2017a, b, 2018a, b). In addition, a USDA grant funded five technicians to monitor the impact of grower applied insecticides on Asian citrus psyllid in 224 orchards in

the five citrus production regions throughout the state (Citrograph article scheduled for fall 2020). Practical experience with the use of pesticides on other citrus pests, combined with an analysis of ACP insecticide trials in Florida and California, led to the following choices for the California bulk citrus treatment list; thiamethoxam (Actara), imidacloprid (Admire Pro and generics), beta-cyfluthrin (Baythroid XL), fenpropathrin (Danitol), fenpyroximate (Fujimite), flupyradifurone (Sivanto) and cyfluthrin (Tombstone) and a cyfluthrin and imidacloprid mixture (Leverage 360) (Table 1, next page). Other factors in selecting insecticides included a short preharvest interval (PHI) and re-entry interval (REI) and established maximum residue levels (MRLs) for key export countries.

Conventional vs. Organic

A frequently asked question is why there are no organic insecticides listed for bulk citrus treatment. By their very nature, organic insecticides are less effective than conventional insecticides and they have an extremely short residual life (hours to days), thus they cannot be depended upon to disinfest an orchard (Bethke et al. 2014). Organic growers are required to use washing or mechanical disinfestation of fruit to remove adult psyllids.

In development: post-harvest fumigation for bulk citrus movement

Treating orchards with broad spectrum insecticides such as pyrethroids or neonicotinoids can cause secondary outbreaks of other pests such as mealybugs, whiteflies, aphids, scales and mites due to the elimination of natural enemies. These pests then require additional insecticide treatments, escalating economic and environmental costs and accelerating pesticide resistance. Registration of a post-harvest treatment of the fumigant ethyl formate is underway and this treatment will replace the foliar bulk citrus sprays. The efficacy of ethyl formate has been demonstrated for Western flower thrips, California red scale, and bean thrips (Pupin et al. 2013, Bikoba et al. 2018). Commercial scale trials designed to disinfest recently harvested fruit were conducted in Riverside, California in 2019. These trials showed that ethyl formate applied as a gas over a 1-hour period to tarped bins of fruit was effective in causing 100% mortality of ACP. Ethyl formate will be registered as a biopesticide, but it will not have organic registration and thus, will not be an organic option. Physical disinfestation by water, rollers or grates will continue to be the method for adult psyllids disinfestation of fruit by organic growers.

Table 1. Bulk Citrus Treatment List http://phpps.cdfa.ca.gov/PE/InteriorExclusion/pdf/acpgrowerinformation.pdf

It is incumbent upon the user to follow all label directions when using any of the products listed below as a foliar application. Reference the California Department of Pesticide Regulation to obtain product and label information: www.cdpr.ca.gov

When applying by ground, use 100-200 gallons per acre (gpa) water volume for mature trees. Adjust water volume for young trees as necessary. When applying by air, use 5-25 gpa water volume depending upon pesticide used.

Products listed below are subject to change.

Product	EPA No.	Active Ingredient	Rate per Acre	Rate of Active Ingredient	PHI	REI	Maximum Amount per Crop Season	Minimum Application Volume by Air
Actara	100-938	25% thiamethoxam	4.0 - 5.5 fl oz	0.063 - 0.086 lb ai thiamethoxam	0d	12h	11 oz maximum per season	5 pga
Admire Pro[1 2 3]	264-827	4.6 lb AI/gal imidacloprid	7 fl oz	0.25 lb AI per acre	0d	12h	14 oz	25 gpa
Baythroid XL	264-840	1 lb AI/gal beta-cyfluthrin	3.2 - 6.4 fl oz	0.025 - 0.050 lb AI beta cyfluthrin	0d	12h	6.4 fl oz of cyfluthrin or beta-cyfluthrin	25 gpa
Danitol 2.4 EC Spray	59639-35	2.4 lb AI/gal fenpropathrin	16 - 21.3 fl oz	0.3 - 0.4 lb AI fenpropathrin	1d	24h	21.3 oz	5 gpa
Fujimite SC	71711-4	Fenpyroximate	2 - 4 pt	0.11 - 0.21 lb AI/acre	3d	12h	8 pints	Not allowed
Fujimite XLO	71711-40	Fenpyroximate	2 - 4 pt	0.11 - 0.21 lb AI/acre	3d	12h	8 pints	Not allowed
Leverage 360	264-1104	1 lb AI/gal beta-cyfluthrin + 2 lb AI/gal imidacloprid	3.2 - 6.4 fl oz	0.025 - 0.50 lb AI beta-cyfluthrin + 0.05 - 0.1 lb AI imidacloprid	0d	12h	6.4 fl oz of cyfluthrin or beta-cyfluthrin	25 gpa
Mustang	279-3126	17.1% by weight zeta cypermethrin	4.3 oz	0.05 lb AI zeta cypermethrin	1d	12h	17.2 fl oz appl. 14 days apart	10 gpa
Sivanto 200 SL	264-1141	Flupyradifurone	10.5 - 14 fl oz	0.144 - 0.183 lbs AI /acre	1d	12h	28 fl oz	10 gpa
Sivanto HL	264-1198	Flupyradifurone	5.5 - 7 fl oz	0.144 - 0.183 lbs AI /acre	1d	12h	14 fl oz	10 gpa
Sivanto Prime	264-1141	Flupyradifurone	10.5 - 14 fl oz	0.144 - 0.183 lbs AI /acre	1d	12h	28 fl oz	10 gpa
Tombstone	34704-912	2 lb AI/gal cyfluthrin	2.0 - 3.2 fl oz	0.10 lb AI cyfluthrin	0d	12h	6.4 fl oz of cyfluthrin or beta-cyfluthrin	25 gpa
Tombstone Helios	34704-978	2 lb AI/gal cyfluthrin	2.0 - 3.2 fl oz	0.10 lb AI cyfluthrin	0d	12h	6.4 fl oz of cyfluthrin or beta-cyfluthrin	25 gpa

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