Topics in Subtropics Newsletter
University of California Cooperative Extension
Fresno, Kern, Madera, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara, Tulare, & Ventura Counties
News from the Subtropical Tree Crop Farm Advisors in California

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(Yeah, it's late)

Editor's Note:

Please let us know if your mailing address has changed, or you would like to add someone else to the mailing list. Call or e-mail the farm advisor in the county where you live. Phone numbers and e-mail addresses can be found in the right column.

Please also let us know if there are specific topics that you would like addressed in subtropical crop production. Copies of Topics in Subtropics may also be downloaded from the county Cooperative Extension websites of the Farm Advisors listed.

Ben Faber
Editor of this issue

Topic **Page**

Special Announcements

Avocado Grower Meetings Change Dates/Times and Places from Previous Years

San Luis Obispo: 1-4, Tuesdays, UCCE Office, SLO
Santa Paul: 9-12, Wednesdays, Logsdon's Resaurant
Temecula: 1-4, Thursdays, South Coast Winery Resort

The same presentations will be given at each venue
Next Series of Meetings are the Weeks of:
February 12-14
April 8-10
June 10-12
August 12-14

For more information call the local advisor in each county where meetings are being held.

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Grower Cooperators Deserve Recognition for Service to Their Industries

Craig Kallsen, Farm Advisor, UCCE Kern Co.

Every agricultural industry in California has a band of private grower cooperators that can be counted on to provide their land, labor and money for scientific research. Most advances in production, now taken for granted as successful standard industry practices, can be traced back to experimentation conducted cooperatively between university-related researchers and cooperating private growers. As a University of California Cooperative Extension Farm Advisor, I work closely with growers and scientific researchers from universities in the commodities to which I have assignments. I have to admit that even after more than a decade of working at this job, I am often amazed at how willing some growers are to become involved in scientific research. Often, cooperating growers provide services to researchers that amount to thousands of dollars per year. While it is true that the growers that allow experimentation on their property have the opportunity to learn from the research first hand, most growers know that the economic gain they receive, in many cases, will fall well short of the investment which they put in the project. Cooperating growers rank high on the selfless scale in that the benefits they receive at the cost of cooperating are shared equally through the industry and yet they volunteer time and again. I have come to realize that what drives this degree of cooperation is not that different from what drives the researchers. I believe the impetus to get involved is an inquiring mind and the realization that one good idea may well pay for all the ideas that weren't so good. Cooperating growers are proud of their industries, they want them to succeed, and they know that investing in science and technology may be the best way to stay ahead of the competition in other countries. Frequently, the hypothesis being tested in scientifically-designed trials on grower properties is a concept originally developed by a grower. Too often the cooperating grower does not get the credit he or she deserves for all time and work that scientific experimentation requires.

It is a pleasure to take this opportunity to highlight the importance of cooperating growers to agriculture and to offer the cooperating grower my sincere appreciation for all they do, will do and have done to make agriculture what it is today.

Citrus Leaf Miner Update

Ben Faber, Farm Advisor, UCCE Santa Barbara/Ventura Cos.

An example of a grower cooperator is Jim Lloyd-Butler who has participated in a study to determine whether it is worth spraying mature lemons to protect them from the damage caused by citrus leaf miner. Looking out over the lemon groves in this area is to see some pretty ragged looking trees. How much if any yield loss does the leaf damage incur and what does it cost to control the pest on mature trees? Work done on orange in Australia, Spain and Florida indicates there is little benefit in controlling the insect on large trees. Young trees on the other hand can mean success or failure of the planting if damage is not controlled.

In Saticoy, we have tried to control leaf damage on mature lemons. From June 2007 until October 2007, seven separate hand applications were made to 20 trees for comparison with 20 trees that were untreated. These were registered chemicals and used in a rotation, as if these were treatments a grower would make. Two applications of spinosad, one of imidacloprid, one of abamectin and two oil alone applications were made during this period. There was not complete control and some damage was present on the treated trees.

One harvest has been made at this time, and the intent is to finish at least eight total harvests to determine if the pest is impacting yield. At this point it would not seem cost effective to control the pest with the expense of applying all these different materials, regardless if yield is affected.

Thanks also to PCA Jane Delahoyde for help with this study.

Stubborn Disease of Citrus in California

Benjamin Rangel and Robert Krueger
USDA-ARS National Clonal Germplasm Repository for Citrus & Dates
Riverside, California

'Stubborn disease of citrus' was first observed about 1915 in 'Washington' navel trees near Redlands. The first report of stubborn from outside of California was from Palestine in 1928. Stubborn is now known to be established in most warm, dry inland producing areas in California and Arizona, and is also a serious disease in most citrus-producing countries with suitable climates. These include countries with arid or semi-arid subtropical climates, but stubborn disease has not been reported from farther east than Iran. In addition, it has not been reported from countries or states with semi-tropical or tropical climates.

The classical concept of citrus stubborn disease involves symptoms expressed in the fruit and in the vegetative growth of citrus trees. Both vegetative and fruit symptoms are often variable and irregularly distributed in the tree.

Fruit symptoms are the most characteristic and the most useful for visual diagnosis in the field. Stubborn-affected trees often flower irregularly (usually in December) and so will have fruits of varying maturity and size present on the tree, although many of the fruit produced on stubborn-affected trees drop while very small. Fruit on stubborn-affected trees produce small fruit that are lop-sided or "acorn-shaped". The skin of the stylar end of the fruit is thin and subject to early breakdown and split, or to stylar-end greening. Color development is often irregular, and frequently stubborn-affected fruit remain green or yellowish-green. Internally, the flesh is dry and the flavor bitter. In normally seedy varieties, there is extensive seed abortion and/or small, under-developed seeds. Another symptom seen less regularly, and generally only when cutting into the fruit, is a blue albedo.

Trees affected by stubborn have "bunchy" growth, with shortened internodes and usually upright leaves. Leaves are often smaller and pointier than normal citrus leaves, and sometimes show a mottle resembling zinc deficiency. Stubborn-affected trees lack vigor and do not flush normally. When flushing does occur, it is often greater in the fall than in the spring. These patterns of vegetative growth result in the characteristic flattened top associated with stubborn-affected trees. In addition, there is often leaf drop and sometimes die-back associated with stubborn.

Trees infected with stubborn early in their life, particularly during the nursery phase, are often extremely stunted and may never attain more than 6 feet in height. This is the classical picture of stubborn disease, and veteran researchers have told us that they did not worry much about stubborn since they selected budwood from large, asymptomatic trees and once the trees were established, an infection with the stubborn pathogen did not have much effect. However, during our investigations the last several years, we have observed large, mature trees with sectors that show stubborn symptoms. These sectoral infections result in a decrease in the amount of salable fruit and thus of economic return. We have also observed trees that are smaller than normal having lower than normal production, but not showing the extreme stunting and negligible yield classically associated with stubborn.

Navel oranges and grapefruits are often severely affected. Valencias generally (but not always) show less symptom development than navels but often drop fruit excessively when ripe. Mandarins seem to show vegetative symptoms more readily than they do fruit symptoms, possibly due to the more variable fruit in mandarins in general. Symptoms are harder to detect in lemons and limes.

Although symptoms and effects of stubborn were well established for many years, the causal agent was unknown and was thought to be a virus. However, in the late 1960's to early 1970's, the causal organism, *Spiroplasma citri*, was identified and characterized as a helical, wall-less bacterium motile in liquid and solid cultures. It has an optimum temperature for growth in culture of about 90 °F. *S. citri* has also been shown to cause various other diseases in crop plants and also affects a number of ornamental plants and several native or invasive species that have become established in

California. *S. citri* is a simple organism with a reduced genome. Most published genes do not reveal any genetic diversity. This is true of the spiralin gene, which is used as the basis of detection by PCR. However, we have detected genetic diversity between stubborn isolates using AFLP.

Diagnosis based upon visual evaluation of symptom expression, particularly fruit symptoms, in severely stubborn-affected trees can be quite reliable. Visual diagnosis of field trees is most effectively done when temperatures are warm and particularly when fruit development is advanced enough that symptoms can clearly be seen (September - October).

In less severe cases of stubborn, positive diagnosis requires confirmation by controlled testing. Biological indexing for stubborn involves graft inoculation of tissue into sensitive varieties, such as 'Madam Vinous' or 'Pineapple' sweet orange, held at warm temperatures. The most definitive detection technique involves culturing the bacterium from vegetative or reproductive tissue, which requires a number of time-consuming and intricate steps. Growth of *S. citri* in culture usually takes 2 – 3 weeks and contamination can result in false positives.

Detection by serological techniques has not proven effective in California. Our recent work has resulted in easier and more reliable detection of *S. citri* using PCR. Initially, we were able to achieve more reliable results from field trees by first putting the appropriate plant parts into culture and then performing PCR on DNA extracted from the medium. We were later able to achieve satisfactory results by performing PCR directly from the culture medium. More recently, we have been able to detect *S. citri* directly from fruit or vegetative tissue by PCR. At this point, the PCR test is more sensitive than the traditional culture method. This is probably due to the fact that during seasons of low titer, growth of the organism in culture is very slow, whereas amplification of the DNA by PCR is less affected by the low titer.

No matter what actual assay is used, detection of *S. citri* is made more difficult by its irregular spatial and temporal distribution. All of the testing methodologies listed above are dependent upon the actual presence of the pathogen in the tissue sampled. In the case of *S. citri*, it cannot be assumed that the pathogen is present in symptomatic trees, nor in all parts of infected trees. Early work demonstrated that stubborn was most detectable during summer months in Riverside. In the San Joaquin Valley, the pathogen becomes routinely detectable slightly later in the year. This is most probably due to winter-time titers of *S. citri* being lower in trees in the San Joaquin Valley as compared to trees in Southern California due to the colder temperatures in the San Joaquin Valley. When we inoculated greenhouse-grown sweet orange indicators with tissue taken from the San Joaquin Valley in December, it took approximately 6 months until the titer had increased enough under these optimal conditions to be detected. *S. citri* is also irregularly distributed in infected trees and does not spread systemically with much efficiency. Therefore, if a tree is infected when it has already obtained some size, only the branch or area near the infection will become symptomatic. In randomly sampling symptomatic trees, we have found only about 15 – 20 % of the samples taken test positive. Because of these factors, a sampling strategy for stubborn is critical. Although not conclusive at this point, we recommend that trees should be sampled in the late summer through early fall (July through October). A fairly large sample of approximately 15 budsticks should be sampled, with samples being taken from symptomatic areas if possible.

Stubborn is a graft-transmissible disease, meaning that it can be spread via budwood. However, the graft-transmissibility of *S. citri* is low and often variable due to the irregular distribution of the pathogen in the tree and the low titers of the pathogen in infected budwood. Because of these factors, a significant proportion of the grafted progeny of an infected tree may be free of *S. citri*. *S. citri* has not been shown to be mechanically transmissible nor transmitted by seed. In the 1970s the natural spread of stubborn by insect vectors was confirmed. The beet leafhopper, *Circulifer tenellus*, was first confirmed to carry the *S. citri* pathogen. Later, *S. citri* was shown to be carried by two other species of leafhopper, *Scaphytopius nitrides* and *S. acutus delongi*, as well as several other species of insects.

In addition to citrus, various other plants have been shown experimentally to be hosts of *S. citri*; however, many of these experimental hosts do not appear to be hosts of *S. citri* in natural conditions. Some of the most important alternate hosts include various members of the *Brassicaceae* (mustard family), which are quite common in California as weeds, native species, or crops. *Brassicaceae* species are also hosts of the beet leafhopper, *C. tenellus*, the most important vector of stubborn disease in California despite citrus not being its preferred host. Most of the *Brassicaceae* that host *S. citri* are winter annuals and harbor the pathogen during the winter months. It appears that during the spring and early summer, *C. tenellus* migrates from the alternate *Brassicaceae* hosts, which are found in the foothill areas surrounding citrus production in the San Joaquin Valley, to the valley floor. The insects remain active as the season progresses and conditions for transmission remain suitable. As mentioned previously, it takes several months for initial infections of *S. citri* to build up in the plant. In the fall, *C. tenellus* migrates away from the valley floor towards the foothills. The foothills stay warmer than the valley floor during the winter months, and so provide a more suitable temperature for both *C. tenellus* and *S. citri*. So, as titer of *S. citri* decreases during the winter months, its perpetuation is assured by its presence in the foothills. Under experimental conditions, *S. citri* maintained *in planta* long-term has been demonstrated to lose its ability to be transmitted and apparently *S. citri* requires passage through the insect vector to retain its infectivity.

This implies that there would be little citrus-to-citrus transmission of stubborn by the leafhopper vectors under most circumstances, with the exception of young plantings. The spread of *S. citri* into citrus plantings apparently mostly comes from the alternate hosts in surrounding fields. Elimination of the pathogen from a grove or nursery would not prevent infection from an inoculum pool in the alternate hosts. The fact that the disease can apparently overwinter in areas removed from commercial production (ie, the foothills around the valley) and then be transported by the vector to the production area during the spring months means that elimination of alternate hosts or the vector from near the orchard would reduce but not eliminate the possibility of infection.

The much lower apparent susceptibility of older trees to infection is an advantage from the disease management standpoint. Orchards established with *S. citri*-free trees in areas in which the populations of the beet leafhopper and the inoculum source in alternate hosts are consistently low for several years after establishment will greatly reduce the chances of stubborn infection and economic losses. The use of *S. citri*-free materials in areas with high *S. citri* presence in alternate hosts and high beet leafhopper activity would probably be of little use in the prevention of stubborn disease during years favorable to disease development. However, the use of pathogen-tested propagative material remains the first line of defense against all economically damaging citrus diseases. Maintenance of mother trees and/or production of young trees under screen provides protection against contamination with stubborn and other insect-vectored diseases and is a recommended practice.

Trap plants have in the past shown some usefulness in managing stubborn. Sugar beets are an attractant for the beet leafhopper but a non-host plant for *S. citri*. Sugar beets planted around a seedling planting of citrus reduced incidence of *S. citri* in periwinkle (an alternate host of *S. citri*) planted around the citrus seedlings by over 50 %. Although this did not provide complete control, the incidence was reduced enough that this strategy deserves consideration. Periwinkles planted around citrus would also provide an indication of the amount of *S citri* present as the periwinkle yellows symptoms develop. Vector control via the use of systemic insecticides has not been shown to be useful in the past in reducing the incidence of stubborn in either citrus seedlings or periwinkles. Antibiotics are effective against *S. citri in vitro* but apparently antibiotics injected into the xylem of large trees are not translocated into the phloem sieve tube elements in sufficient amounts for affected trees to improve.

Removal of stubborn-infected trees or branches is often practiced by growers. This is most effective in younger plantings, as it is at this stage that the trees are most susceptible to infection. Trees infected early in their life will never be productive, so, stubborn-infected trees in plantings less than 6 years old should be removed as soon as they are diagnosed. Trees that become infected after they are mature present only a small hazard to the rest of the grove since there is little tree-to-tree spread. It is mainly economic factors that will determine whether mature trees should be removed. Control of alternate hosts near these plantings will reduce (but not eliminate) the possibility of infection of re-planted trees.

In summary, the following are considered to be useful in lowering the incidence of stubborn or minimizing losses from it:

1. If possible, locate nurseries in areas where stubborn does not spread naturally and where the incidence of stubborn is low.
2. Use *S. citri*-free budwood for all propagations including topworking.
3. If possible, maintain mother trees under screen and if possible produce nursery trees in a protected environment (greenhouse or screenhouse).
4. Topworking should only be done on trees that are totally free of *S citri*.
5. On an annual basis, remove all stubborn-infected trees from orchards less than 6 years old.
6. All replants in orchards of any age should be removed if infected with stubborn and again replanted with stubborn-free trees.
7. Maintain a strict program of weed control in and around the planted orchards, particularly for the first 6 years.
8. In nurseries located in areas where *S citri* is endemic, substantial borders of attractive trap plants that are not hosts to *S. citri* can be used. The traps plants can also be treated with insecticides to kill the attracted leafhoppers.
9. Avoid the use of cover crops susceptible to *S. citri* in orchards less than 6 years old in areas with high populations of the insect vectors.

Acknowledgements

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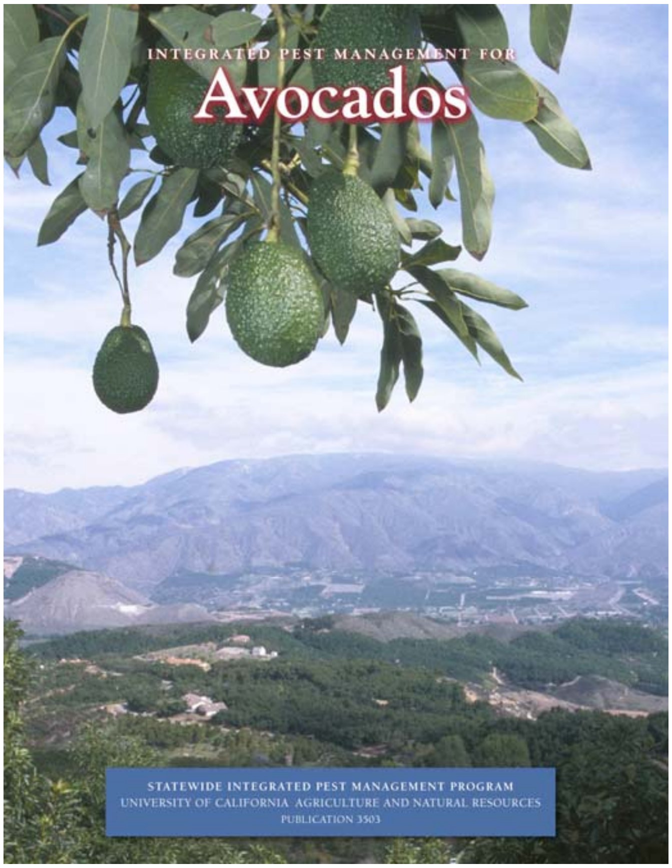

Integrated Pest Management for Avocados (2008)
New from the University of California, Agriculture & Natural Resources:
This UC IPM manual for avocado growers and pest control professionals uses the most up-to-date research available from University of California faculty and Cooperative Extension specialists, farm advisors, and pest control advisers. The manual is illustrated with nearly 400 high-quality color photographs, plus line drawings and charts that will help you identify and manage over 100 important pests and disorders.

Using this guide you'll learn how to:

- Prevent and diagnose causes of damage;
- Identify pests and key natural enemies;
- Establish an IPM program for your grove;
- Use biological control and other nonchemical methods;
- Manage problems related to irrigation, nutrition, and the growing environment; and
- Determine when direct control actions are warranted.

IPM for Avocados is designed for use with the 2007 revision of the *UC IPM Pest Management Guidelines: Avocado* and the new seasonal decision-making guide, the Avocado Year-Round IPM Program, both online at www.ipm.ucdavis.edu.

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