Pest Management Strategic Plan

for

Citrus Production

in

California

December 2009

The purpose of this document is to provide the citrus industry, state and federal regulatory agencies, and pesticide manufacturers with the current status of pest management for citrus in California. The Citrus Pest Management Strategic Plan will be an ever-evolving document which will be modified as pest management strategies change.

The California Citrus Quality Council coordinated the development of the Citrus Pest Management Strategic Plan in cooperation with:

- *Citrus Research Board*
- *Grower and packing house personnel*
- *Citrus growers*
- *University of California Cooperative Extension and Agricultural Experiment Station (AES) Faculty*
- *Pest control advisors*
- *USDA ARS federal research personnel*

For information regarding this document, please contact:

California Citrus Quality Council
210 Magnolia Avenue, Suite 3
Auburn, CA 95603
530.885.1894 (phone)
530.885.1546 (fax)

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Beth Grafton-Cardwell, UC Riverside

Wally Ewart, CA Citrus Quality Council

Rick Melnicoe, UC IPM, Davis

Neil O'Connell, UCCE, Tulare

Jim Adaskaveg, UC Riverside

Georgios Vidalakis, UC Riverside

Anil Shrestha, UC, Kearney Ag Center

Carol Lovatt, UC Riverside

Brad Hansen, ARS-USDA

Kim Wilenius, C&M Nursery

Gary Moles, Willits & Newcomb

David Haviland, UCCE Kern

Richard Dunn, Badger Farming Co.

Joseph Morse, UC Riverside

Bob Luck, UC Riverside

Phil Phillips, UC IPM, Ventura

Julie Doctor, Sunkist

Bob Blakely, CA Citrus Mutual

Leonard Massey, B & Z Nursery

Joe Barcinas, ICE

Jim Wells, Environmental Solutions Group

Alistair McKay, Sunkist

Helga Förster, UC Riverside

Kathie Blyskal, Sunkist

Charlene Jewell, FMC Technologies

Chuck Orman, CCQC/Sunkist

Joseph Smilanick, USDA-ARS

Bob Elliott, CCQC/Sunkist

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Production
California produces 88% of the lemons, 56% of the tangerines, 22% of the oranges, and 17% of the grapefruit commercially grown in the United States. "Tangerines" include tangerines, mandarins, tangelos, and tangors.

In 2008/09**,** California was first in the nation in the production of lemons and tangerines and second in the production of oranges and grapefruits. Overall, California is second in citrus production. Florida is first, Texas is third, and Arizona ranks fourth (1).

Acreage
In 2008/09, citrus were harvested in California from a total of about 269,600 acres, as follows (1):

Oranges	186,000 acres (75% Navel and 25% Valencia)	(69%)
Lemons	47,000 acres	(17.4%)
Tangerines	27,000 acres	(10%)
Grapefruit	9,600 acres	(3.5%)

Production Value
In 2008/09, the value of California's overall citrus crop was about $1,158,725,000 (1).

The Production Values were as follows:

Crop	Value	
Oranges	$626,174,000	(54%)
Lemons	$313,026,000	(27%)
Tangerines	$163,031,000	(14%)
Grapefruit	$ 56,504,000	(5%)

Fresh-Market
The primary end-product of citrus grown in California is fresh-market. For oranges, 98% of the production value is fresh compared to Florida where only 5% of the crop value is fresh-market. For grapefruit, nearly 100% of the crop is fresh-market. For lemons, about 59% of the crop is fresh-market (1).

Export Value
California exports approximately 65% of the citrus harvest value to other countries. The value of these exports in 2007 was $**378** million for oranges, $**141** million for lemons, and $**11** million for tangerines and mandarins and $**39** million for grapefruit (3). Major export markets include Canada, Korea, Japan, Hong Kong, Australia and China.

Cost Per Acre
In California the total cost to produce an acre of citrus ranges from $5,000 to $10,000 with production in the San Joaquin Valley region the most costly (8, 9). Production costs prior to harvesting are around $1,000 to $3,000 per acre. In 2002, there were approximately 6,500 citrus growers (9).

Integrated Pest Management
Citrus production in California follows one of the strongest integrated pest management (IPM) systems in the state.

Production Regions

- San Joaquin Valley Region
- Coastal-Intermediate Region
- Interior Region
- Desert Region

In addition, there is a small citrus growing area in the Northern Sacramento Valley where mainly tangerines are grown (8).

San Joaquin Valley Region. More than half the value of citrus is from the San Joaquin Valley region) (3). This region has hot and dry summers and winters that are typically cold and wet (8). Most of the value of the state's orange production, about 87%, is located in this region. About 80% of the state's tangerine's value is from the San Joaquin Valley. The value of the lemons from this region is 26% of the state's total. For grapefruit nearly 25% of value of the state's total is from this region (3).

Coastal-Intermediate Region. The coastal-intermediate region, from Santa Barbara County south to the San Diego/Mexico border, has a milder climate influenced by marine air (8). The region differs from the Interior Region in climate, cultivars grown, and pest problems. The Coastal Intermediate and Interior regions account for the majority (more than 54%), of the value of the state's lemon production. Approximately 23% of the grapefruit production value is from the coastal-intermediate region. For oranges, the coastal-intermediate region emphasizes Valencia production with only limited acreage producing Navel oranges. Only limited acres are devoted to tangerine production.

Interior Region. The interior region includes western Riverside and San Bernardino counties, inland portions of San Diego, Orange, and Los Angeles Counties and other growing regions that are only marginally affected by the coastal climate. In contrast, the coastal intermediate district is significantly influenced by the moderating coastal climate (8). The interior district tends to be warmer and dryer in the summer and colder in the winter than the coast.

Desert Region. The desert region, primarily the Coachella and Imperial Valleys, produces citrus under conditions where temperatures fluctuate widely between day and night, with low humidity most of the year (8). The desert region is the primary location for production of grapefruit, with about 74% of the state's crop value being produced in a region that represents less than 20% of the state's citrus growing acreage. About 15% of the state's tangerine production comes from the desert region.

Citrus Crops. Oranges, lemons, grapefruit, tangerines, kumquats, and various other citrus crops are grown in California. For purposes of this Pest Management Analysis, tangerines refer not only to tangerines, but also mandarins, tangelos, and tangors. Lime production and pest management issues are included with those discussed for lemons, since lemons and limes are produced in the same regions within California.

Varieties. There are a few varieties of citrus that dominate California's production. The primary varieties are as follows:

> **Washington Navel Oranges** are predominantly grown in the San Joaquin Valley where it takes about 9 months for fruit to mature (8). About 94% of the state's Navel orange acreage is in this region (3). The main harvest is from late fall through early spring and sometimes into early summer.
>
> **Valencia Oranges** are typically grown in the coastal-intermediate and interior areas for the fresh market. Valencia oranges mature in 12 to 15 months and are harvested from spring through late fall (8). About 24% of the Valencia oranges are grown in the coastal-intermediate and interior regions, and 65% in the San Joaquin Valley region (3).
>
> **Eureka Lemons** are the most common cultivar in the coastal-intermediate region, where approximately 65% of the state's lemon acreage is located (3, 8).
>
> **Lisbon Lemons** are better adapted to the Desert, Interior and San Joaquin Valley regions. Mature fruit are harvested over a 9-month period (8). About 35% of the state's lemon acreage is in these growing regions (3).
>
> **Marsh Grapefruit** are grown in the desert valley regions where they are harvested in the winter and early spring (8). About 66% of the state's grapefruit acreage is in the desert region (3).
>
> **Tangerine** varieties are primarily grown in the desert region (22%) and the San Joaquin Valley region (72%) (3,8).

All growing regions have some acreage of nearly all major cultivars.

THE DISTRIBUTION OF CITRUS COMMODITIES WITHIN THESE REGIONS IS SUMMARIZED IN TABLE 1 BELOW:

TABLE 1 – Most recent data available.

Region	Lemons	Navels	Valencias	Grapefruit	Tangerines
Interior	1%	2%	3%	5%	0%
Coastal	65%	1%	24%	23%	5%
San Joaquin Valley	17%	94%	65%	6%	72%
Desert	17%	3%	8%	66%	22%

FOUNDATION FOR PEST MANAGEMENT STRATEGIC PLAN

In the subtropical climate of California, trees of all citrus cultivars, except coastal lemons, stop growing during the winter. During this period, the tree maintains a base level of water transport and starch consumption. The main growth flush appears in late February and March. Leaves stay on the tree for 1 to 2 years. They are replaced continually, although leaf drop is greatest during the spring flowering period. Citrus usually bloom abundantly but most flowers and young fruit drop (early drop). A combination of environmental and physiological factors seems to determine which flowers develop into fruit that persist to harvest. Unlike deciduous fruit, citrus fruit have no clearly identifiable point of maturity. Color can serve as an approximate guide but is generally not reliable because color development depends largely on temperature, especially low night temperature, and mineral nutrition of the tree.

Citrus production in California is one of the state's best examples of an integrated approach to pest management. In an effort to maximize the appropriate control of economically important pests, California's citrus industry recognizes that a cost-effective program must ensure that pest management tools are not lost due to the onset of resistance. Pest levels are monitored closely to ensure that pest management decisions are initiated prudently and carefully coordinated. As a result, all growers use a mixture of cultural, biological, and chemical control practices to manage economically important pests.

This document is an analysis of regional and seasonal pest occurrences, agronomic practices, and pest management tools used during the major stages of the citrus production season. In some cases, certain sections will be divided by area or season to describe regional differences. In addition, critical issues facing the citrus industry in California will be prioritized. These critical issues may be regulatory, educational, or research in nature.

Activities and Outcomes from the Previous PMSP

A number of priority critical needs have been met since the previous PMSP was developed in 2004. The glassy-winged sharpshooter (GWSS) has become less of a pest in citrus because the USDA areawide programs utilized neonicotinoid insecticides to suppress the spread of GWSS. Research indicated that treatments reduce GWSS for 3-5 years and disrupt natural enemies during the year of treatment. These treatments have been made compatible with IPM through infrequent use.

While research on ant bait systems continued through the 2004-9 period, they have achieved only partial success on Argentine ants. Additional ant species are found in citrus and bait systems are still needed for these ants. Natural enemies of citrus peelminer and leafminer were released and studied in the San Joaquin Valley. There is evidence of their effect on peelminer populations but no evidence of their overwintering. Research was conducted on bean thrips that determined that trap cards were not a good indicator of pest densities, resulting in changes in the protocols for Australia to detect bean thrips. A satisfactory disinfestation treatment was sought in research using ozone, Evergreen* and Turbocide*, but none was found. Studies on cold tolerance of bean thrips indicate that few live bean thrips

*Other trade names may apply

should survive transport to Australia. Resistance to several pesticides was documented in studies on California red scale, citricola scale and citrus thrips. New insecticides, Movento *(for red scale) and Delegate* (for citrus thrips) were registered. Codex MRLs and some export market standards were established for the following insecticides: Assail*; Esteem*; Applaud*; Provado*; Baythroid*; Danitol*; Success*. The MRL for Lorsban* on citrus in Japan was increased to the same level as the US (1ppm).

The registration and establishment of Codex and some export MRLs were completed for new postharvest fungicides Penbotec*, Scholar* and Abound*. Implementation of postharvest use has been delayed by the lack of MRLs in key export markets. Resistance management guidelines for these new fungicides have been developed for the expected increased use of these materials.

The industry continued to support international harmonization of MRLs for citrus thru contacts with US EPA, USDA and commodity organizations. Following citrus industry initiative, the Codex process for setting MRLs has been improved resulting in new MRLs as quickly as 18 months. The industry also worked with USDA and EPA to develop and maintain an MRL data base for more than 50 countries including Codex and regional standards.

*Other trade names may apply

STAGES OF CITRUS PRODUCTION BY GEOGRAPHIC AREA

Major Stages of Citrus Production Seasons -- San Joaquin Valley

	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov
Pre Bloom				C	C							
Bloom				C	C							
Petal Fall					C	C						
Growing Season (June-Sept)							C	C	C	C		
Growing Season (Oct thru Jan)	C	C									C	C
Harvest	N, L, G, T	N, L, G, T	N, L, G, T	N, L, G, T, V	N, L, G, T, V	N, V,	N, V	V	V	V	N, V, G, T	N, V, G, T
In-Field Postharvest	C	C	C	C	C	C	C	C	C	C	C	C

Major Stages of Citrus Production Seasons -- Southern Interior

	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov
Pre Bloom			C	C								
Bloom				C	C							
Petal Fall					C	C						
Growing Season (June-Sept)							C	C	C	C		
Growing Season (Oct thru Jan)	C	C									C	C
Harvest	N, L, T	N, L, T	N, L, , T	N, L, T, V	N, L, G, T, V	N, V, G	G, V	V, G	V, G	V, G	V, G,	V
In-Field Postharvest	C	C	C	C	C	C	C	C	C	C	C	C

Major Stages of Citrus Production Seasons -- Coastal

	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov
Pre Bloom			C	C								
Bloom				C	C							
Petal Fall					C	C						
Growing Season (June-Sept)							C	C	C	C		
Growing Season (Oct thru Jan)	C	C									C	C
Harvest	N, L, V	N, L,	N, L,,	N, L,	N, L,	V, L	V, L	V, L	V, L	V, L	V, L	V, L
In-Field Postharvest	C	C	C	C	C	C	C	C	C	C	C	C

Key: N = Navel Oranges, V = Valencia Oranges, L = Lemons, G = Grapefruit, T = Tangerine, C = All Citrus Varieties

Footnote: For lemons grown on the coast, there are 3 major blooms per year, resulting in a year-round harvest.

STAGES OF CITRUS PRODUCTION BY GEOGRAPHIC AREA (continued)

Major Stages of Citrus Production Seasons -- Desert

	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov
Pre Bloom			C	C								
Bloom				C	C							
Petal Fall					C	C						
Growing Season (June-Sept)							C	C	C	C		
Growing Season (Oct thru Jan)	C	C									C	C
Harvest	G, L, T	G,L, T, V	G, L, T, V	L, T, V, G	G, T, V	V, G	G			L	L, G, T	L, G, T
In-Field Postharvest	C	C	C	C	C	C	C	C	C	C	C	C

Key: N = Navel Oranges, V = Valencia Oranges, L = Lemons, G = Grapefruit, T = Tangerine, C = All Citrus Varieties

Footnote: For lemons grown on the coast, there are 3 major blooms per year, resulting in a year-round harvest.

PEST MANAGEMENT PRIOR TO OR AT PLANTING

The best Integrated Pest Management (IPM) methods are those that enable development of a strong root system, prevent pest outbreaks and provide long-term and economical control. Preventative methods include following quarantine regulations, removing sources of new infection, choosing scion cultivars and rootstocks less susceptible to pest damage, installing an appropriate irrigation system, providing conditions that enhance the activities of natural enemies of pests, and carrying out various management activities correctly.

Citrus Nematode management

Citrus is grown on soils with widely differing textures and depths but it performs best on medium to deep soil that drains well. One of the key pests causing "slow decline" of citrus is the citrus nematode, *Tylenchus semipenetrans*. It is reported to be present in most citrus orchards and in all soil types. Citrus nematodes attack roots by burrowing their anterior end deep inside the root cortex while the posterior end remains outside, in the soil. Good sanitation practices are essential to avoid nematode infestations. Use certified nematode-free material for planting. Rotation with annual crops for 1 to 3 years before replanting citrus reduces the replant problem and helps to reduce citrus nematode populations. Using a resistant rootstock is recommended whether or not nematodes are present. If the site was previously infested with nematode pests of citrus, pre-plant fumigation may be necessary to reduce nematode population levels. When replanting a citrus orchard, a pre-plant treatment is recommended even if a resistant rootstock is used. In established orchards (post-plant), consider treatment when sampling indicates more than 400 female citrus nematodes in 1 gram of roots in February to April or more than 700 in 1 gram of roots during May and June.

Pre-plant Treatments

1. **1,3-Dichloropropene** (Telone II*, Telone C-35*, or In-Line*): This is a good soil fumigant but the current rate of 332 lbs../acre is too low for optimal performance in finer textured soils. 1,3-D Dichloropropene is an effective replacement for deeply dried sandy loam soils where it can correct much of the replant problem and can control nematodes to 5 feet deep at 99.9% level.
2. **Chloropicrin** (Nutrapic, Tri-Clor*): Effective as a nematicide in citrus, however, the rate (approximately 300 to 350 lbs./acre) needs to be further evaluated. Pic is a relatively poor root penetrant but citrus roots are relatively small. It moves better through the soil than the same amount of Telone.
3. **Methyl isothiocyanate liberators** (Vapam HL*, K-Pam*, or Sectagon*): Can be effectively applied as a soil drench to moist soils that are porous. Equipment to accomplish a good treatment without odors is not available to growers. The smaller and shallower roots of citrus lend themselves to this treatment. These products will not perform well where clods (blocky soil structure) are large.
4. **Sodium tetrathiocarbonate** (generates carbon disulfide) (Enzone*): Is a poor root penetrant and should not be considered as a pre-plant treatment unless good field data become available. This non-explosive compound slowly releases carbon disulfide. There is no new field data on file at DPR or on the IR-4 website.

*Other trade names may apply

<u>Post-plant Treatments</u>

1. **Fenamiphos** (Nemacur*): At 1 gallon per acre, it has been the most used post-plant nematicide for citrus. It can provide 50 to 75% reduction of citrus nematode for 6 months. There has been some concern regarding its performance after several years. (As of May 31, 2008 – Nemacur will no longer be available; stocks in possession of growers may be depleted, but manufacturing, sale and distribution ceased as of May 31, 2007. Registrant cancelled all registrations containing this active ingredient.)
2. **Imidacloprid** (Admire*): Recent nematode sampling has revealed short-term suppression but not control of nematodes attributable to Admire insecticide applications. Admire is registered in CA for citrus, but not for nematodes.
3. **Spirotetramat** (Movento*): Recently registered for citrus, but not specifically for nematodes. Research has shown some nematode suppression, but not a consistent response. Research is underway to determine the factors involved.
4. ***Myrothecium* spp.** (Ditera*): Has been sold as an EC and more recently as DF formulations. The general recommended rate of application is 20 lbs/acre several times per year although this treatment regimen may not be best for citrus. This product can be applied during the summer months. Efficacy against nematodes is doubtful.
5. **Oxamyl** (Vydate 4L*): Product is expensive and has shorter half-life than Nemacur. Does not perform as well as Nemacur but does stimulate carbamate growth responses.
6. **Sodium tetrathiocarbonate** (generates carbon disulfide) (Enzone*): Is applied at 750 to 1000 ppm via microsprinkler or drip. This product should be applied between March and May or October and December. Control of citrus nematode should be 50 to 75% for 6 months. The impact on citrus roots and level of Phytophthora control afforded is unclear. Yield data following repeated treatments still needs some research. Use of this product has been slow to develop within the citrus industry. For both pre- and postplant treatments, only sodium tetrathiocarbonate is for Armillaria root rot.
7. **Chloropicrin** may have some benefits in some pathosystems but not against any citrus fungal pathogens.

Non-registered products with potential for use by the citrus industry

1. **Azadirachtin** (Agroneem*): A Neem product that moves better through soil when added to Integrate. Trials have been initiated. Registered at DPR, nematodes are a listed pest, and citrus is a listed site.
2. **DMDS** (dimethyl disulfide*): Unevaluated against fungal pathogens of citrus.
3. **Furfural** (Agriguard*) Registered at EPA, fumigant for fully enclosed structures only – for nematodes and fungal plant diseases; not yet registered at DPR.
4. **Humic Acid** (Integrate*): This is a humic acid derivative used as a soil amendment. Trials have been initiated.
5. **Methyl Iodide** (Midas*): registered at EPA, CA – currently delayed, under evaluation.
6. **Plant Extract** (Sincosin*): Previous tests at 20 lbs/acre show good performance on citrus nematode but chemical mixtures like this need quality assurance.
   To validate these results more data development is needed.
7. **Sodium Azide:** Unlikely to get widespread registration, highly toxic.
8. **Walnut tree** (Walnut Tea*): A new botanical product from ground walnut trees. Trials have been initiated.

*Other trade names may apply

CITRUS DISEASES

Pre-Harvest Diseases**

**** Includes the period between planting & harvest**

<u>FUNGAL DISEASES</u>

<u>Phytophthora Root Rot</u> - Caused by *Phytophthora* spp.

- Cultural: Needs to be practiced season-long. Avoid over-irrigation, provide good soil drainage. Practice good sanitation. Plant resistant, certified, nursery rootstock when possible. Practice mulching which has an especially positive effect on young tree plantings and increases biological activity in the soil. Use of non-ionic surfactants can improve both soil drainage and disease control; however, high rates are required that are not economical.
- Biological: None currently available. Research needed for organic production.
- Chemical <u>(Fumigants)</u> (pre-plant): None of these fumigants work on Phytophthora. (see comments above)
  1. **Chloropicrin** (Nutrapic, Tri-Clor*): Applied pre-plant by means of injection. Lower rates are applied on sandy loam and higher rates are used on heavier soils. Does not provide consistent control of soil-borne pathogens and is weak on several weed species.
  2. **Sodium tetrathiocarbonate** (Enzone*): Is generally considered to be less efficacious than the other registered alternatives as it is a poor root penetrant of dead roots. It is the most suitable of the soil fumigants for post-plant treatments. Product needs further testing.

*Other trade names may apply

Fungicides

1. **Mefenoxam** (Ridomil Gold*): Post-planting application. 2-3 applications per year. For 2 applications, generally make an application in the spring (May or prior to first root flush) and in the summer (August or prior to second root flush). When making 3 applications, one application should be in April, followed by one in late May, and one in August. Highly effective, however, there is documented resistance in pathogen populations.
2. **Fosetyl-Al** (Aliette*): Highly effective. No known documented resistance. Limitations: expensive. Same timing of application as Ridomil Gold*.
   - **Metalaxyl** (Ridomil * see above Mefenoxam*): Soil pre-plant (previously registered as Ridomil), Subdue is only other mefenoxam for citrus, but it is for non-bearing plants only. (pre-plant soil, for all citrus fruits)
   - **Sodium tetrathiocarbonate** (Enzone*): Has shorter residual period. Cannot be used as a stand-alone fungicide.
   - **Phosphorous acid products** (Fungi-Phite*, Ele-Max* Foliar Phosphite* and other trade names*) Similar in performance to Aliette*.

Phytophthora gummosis - Caused by *Phytophthora* spp.

- Cultural: Avoid standing water around trunk; prevent sprinkler water from hitting trunk, prevent wounding of tree while pruning suckers (limit use of weed eaters). Plant on berms to help drainage. Propagate with bud union 6-8 inches above soil line.
  Resistant rootstocks – Avoid planting susceptible rootstocks such as rough lemon.
- Biological: None currently available.
- Chemical: Same fungicidal treatments (both pre- and post-plant application) as for Phytophthora root rot.
  - **Phosphorous acid products** (Fungi-Phite*) Similar in performance to Aliette*.

Dry Root Rot - Caused by *Fusarium* spp**.**

- Cultural: Avoid injury to trunk and crown. Employ good irrigation practices. Practice mounding which increases soil drainage around the tree. Use healthy, non-injured rootstock. Aerate around diseased trees. Practice sanitation by removing any diseased trees.
- Biological: None available at this time.
- Chemical: None available at this time.

Armillaria Root Rot – Caused by *Armillaria mellea*

- Cultural: Select disease-free sites whenever possible. Avoid sites that were previously oak woodland areas. Practice year-round irrigation and drainage management. Employ mitigation measures. Remove infected trees including roots larger than pencil thickness. Use physical barriers if needed.
- Biological: None available at this time.
- Chemical: See pre- and post-plant treatments

*Other trade names may apply

Brown Rot/Fruit Rot – Caused by a Complex of *Phytophthora* spp.

- Cultural: Skirt pruning, practice year-round irrigation and drainage management. Plant cover crops to prevent splashing and therefore spread of disease, (not a common practice, cover crops are undesirable during winter months due to frost concerns.) Sanitation: Avoid picking from lower part of the tree immediately after a rain.
- Biological: None currently available.
- Chemical:
    - **Copper products:** (many products and formulations of copper sulfate and fixed (neutral) coppers available) (use as a preventative applied in the late fall/winter season, before winter rains and re-apply if heavy rainfall occurs during the winter season). Common application strategies include spraying lower 2/3 of the tree. Limitations: Some phytotoxicity may occur (burns fruit and leaves). Copper sulfate must be 'safened' with hydrated lime and fixed coppers are also generally used with lime to improve persistence. Highly effective. Oil applied before or immediately after may reduce the effectiveness and may increase copper injury.
    - **Fosetyl-Al** (Aliette*): Timing – applied together with a fall (Sept., Oct., Nov.) spray for bud mite. 30 day PHI which makes use of this product problematic. Highly effective though expensive product.
    - **Phosphorous acid products** – same as Aliette*.

Septoria Spot – Caused by *Septoria citri*
A fungal disease of fruit, leaves and twigs causing dieback. On leaves, symptoms include small circular spots that may enlarge and coalesce and may be surrounded by yellow halos. On fruit, lesions consist of small depressions or pits that extend no deeper than the flavedo. During storage, lesions may enlarge and coalesce into conspicuous brown to black sunken blotches several centimeters in diameter. A tear stain symptom may also be associated with fruit infections.

- Cultural: Prune back dead and dying branches to remove source of inoculum. Plant lemon varieties that have fewer thorns; i.e. Eureka as opposed to Lisbon.
- Biological: None available at this time.
- Chemical:
    - **Copper products:** (many products and formulations of copper sulfate and fixed (neutral) coppers available). Use copper-based products mixed with zinc sulfate. Use as a preventative applied in the late fall/winter season. Limitations: Some phytotoxicity (burns fruit and leaves). Coppers must be 'safened' with hydrated lime and fixed coppers are also generally used with lime to improve persistence. Highly effective against *Septoria citri*. Has shorter residual period under wet conditions. Applications should cover entire tree using fixed and nonfixed coppers. Oil applied before or immediately after may reduce the effectiveness and may increase copper injury.
    - **Zinc products:** (zinc sulfate, fixed zinc products) Mixed with copper fungicides in Bordeaux mixtures.
    - **Azoxystrobin** (Abound*)**:** research results indicate potential usage as protective rotational treatments with copper for managing Septoria spot.
    - **Chlorothalonil** (Bravo*): not registered but under evaluation.

*Other trade names may apply

Botrytis Rot – Caused by *Botrytis cinera*

Mainly a pre-harvest problem (primarily coastal regions)

- Cultural: Avoid mechanical injuries. Avoid wind damage by planting windbreaks. Employ frost protection.
- Biological: None currently available.
- Chemical: None currently available.
  - **Copper products:** Use as a preventative applied in the late fall/early winter season, before winter rains, and re-apply if heavy rainfall occurs during the winter season. Limitations: Some phytotoxicity (burns fruit and leaves). Copper products must be safened with hydrated lime and fixed coppers are also generally used with lime to improve persistence. Highly effective. Has shorter residual period under wet conditions. Applications should cover entire tree. Oil applied before or immediately after may reduce the effectiveness and may increase copper injury.

Anthracnose – Caused by *Colletotrichum gloeosporioides*

A fungal disease of leaves, fruit, and twigs. Symptoms include marginal leaf chlorosis and necrosis, twig diebacks, and fruit infections that result in tear stain symptoms on the rind and fruit decays. Generally, the disease only develops under warm and very wet weather conditions during the winter season. Seen more often on grapefruit and Navel oranges in the southern growing regions of the state. This disease is seen sporadically.

- Cultural: Prune back dead or dying branches to remove source of inoculum.
- Biological: None available at this time.
- Chemical:
  - **Copper products**: although registered, have little efficacy
  - **Azoxystrobin** (Abound*): efficacious but with planned registration of this material as a postharvest tool, the potential exists for resistance to develop (single site mode of action presents problems). Application timing: Apply in late December to early January before disease develops after warm, wet rains.
  - **T-methyl:** Arysta LifeScience's product, a benzimidazole fungicide – generic formulation of thiophanate-methyl, but it is not registered. Potential registration as a benomyl replacement but costly registration requirements are a deterrent. Topsin-M *registrant withdrew from registration attempts.

Clear Rot - early symptom of field infections caused by *Penicillium* spp. *(Infrequent pre-harvest disease) This is not sour rot but an early stage of Penicillium decay.*

- Cultural: None available at this time as it is a ubiquitous organism.
- Biological: None available at this time.
- Chemical:
  - **Azoxystrobin** (Abound*) – Efficacious but with planned registration of this material as a postharvest tool, the potential exists for resistance to develop (single site mode of action presents problems). Still needs intermittent disease control. Application timing: 3 weeks pre-harvest.
    Pyrimethanil (Scala*) – Registered on lemons only (Comments similar to Azoxystrobin)
  - Fludioxonil/cyprodonil (Switch*) – Registered for lemons and limes (Comments similar to Azoxystrobin)

*Other trade names may apply

Hyphoderma gummosis – *Caused by Hyphoderma sambuci_Causes a decline of scaffold branches and whole trees. A wood decay fungus that can invade the cambium of lemon trees and possibly other citrus species once wood-exposing injuries occur from biological (i.e., animals) or environmental factors (i.e., cold injury).*

- *Biological:Trichoderma harzianum is registered as Plant Shield HC* on citrus and is used as a pruning wound treatment.*
- *Chemical: Numerous fungicides have been evaluated and have not been shown to be effective in field trials.*

*Other trade names may apply

PROKARYOTIC (BACTERIAL) DISEASES

Bacterial Blast *(Pseudomonas syringae)*

- Cultural: Reduce wind injury with wind breaks. Prune out dead/dying wood. Weaker trees are more susceptible to blast. Proper timing of fertilizer is important as you should avoid succulent growth prior to the wet periods of the year; i.e. late fall. Field sanitation is also critical prior to and during the rainy season.
- Biological: None available at this time.
- Chemical:
  - **Copper products:** Have limited efficacy against this disease. High rates are needed which may result in phytotoxicity and discoloration.

Stubborn Disease (*Spiroplasma citri*)

Naturally spread by leafhoppers

- Cultural: Management of stubborn disease focuses on preventing the disease and avoiding its spread. Use only certified or disease tested (stubborn-free) material when you plant or propagate.
- Biological: None available at this time.
- Chemical: None available at this time.

VIRUS AND VIROID DISEASES

Cachexia/Xyloporosis (Citrus variants of the *Hop stunt viroid*-HSVd, namely: citrus viroid IIb & IIc, CVd-IIb & CVd-IIc)**:**

- Cultural: Remove infected trees. Avoid cross contamination when pruning by thoroughly disinfecting pruning clippers and saw with 0.5 to 1.0% sodium hypochlorite solution (commercial bleach). Use only certified or disease tested (cachexia-free) material when you plant, propagate, or topwork especially when using the cachexia sensitive mandarins and mandarin hybrids (tangors & tangelos), alemow (citrus macrophylla), and limes.
- Biological: None available at this time.
- Chemical: None available at this time.

Exocortis (*Citrus exocortis viroid*-CEVd)**:**

- Cultural: Remove infected trees. Avoid cross contamination when pruning by thoroughly disinfecting pruning clippers and saw with 0.5 to 1.0% sodium hypochlorite solution (commercial bleach). Use only certified or disease tested (exocortis-free) material when you plant, propagate, or topwork especially when using the exocortis sensitive trifoliate and trifoliate hybrids rootstocks.
- Biological: None available at this time.
- Chemical: None available at this time.

Psorosis (*Citrus psorosis ophiovirus*-CPsV)

- Cultural: Use disease-free budwood. Remove infected trees. Avoid cross contamination when pruning by thoroughly disinfecting pruning clippers and saw with 0.5 to 1.0% sodium hypochlorite solution (commercial bleach). Use only certified or disease tested (psorosis-free) material when you plant, propagate, or topwork.
- Biological: None available at this time.
- Chemical: None available at this time.

Tristeza (*Citrus tristeza closterovirus*-CTV)

Naturally spread by aphids. Causes quick decline; stem pitting and seedlings to yellow.

- Cultural: Use tolerant rootstocks (i.e. trifoliate and trifoliate hybrids). Use only certified or disease tested (tristeza-free) material when you plant, propagate, or topwork. Avoid cross contamination when pruning by thoroughly disinfecting pruning clippers and saw with 0.5 to 1.0% sodium hypochlorite solution (commercial bleach).
- Biological: None available at this time.
- Chemical: None available at this time.

OTHER CITRUS VIRAL DISEASES

The following citrus diseases have been reported to be present in California but do not cause any significant economic losses. Some of them have the potential to rise to important problems due to specific cultural practices or pathogen properties. The potential damage of these diseases can be minimized with the use of certified or disease tested propagative material (budwood and seed) for new plantings or topworked orchards, as well as sanitation practices mainly disinfection of pruning tools with 0.5 to 1.0% sodium hypochlorite solution (commercial bleach).

Concave gum-Blind pocket (unknown)

The disease has been reported in California but it is not associated with any significant economic losses. The citrus most sensitive to the disease include mandarin and mandarin hybrids (i.e. tangor), sweet orange, and grapefruit. The biggest concern for this disease is the report of seed transmission, a very rare phenomenon for citrus viral diseases.

Infectious Variegation, Leaf Rugose, & Crinkly leaf (Different Illarviruses)

The disease has been reported in California but symptoms are usually mild and have no significant economic effects. The most sensitive citrus types are lemon, sour orange, citron and grapefruit.

Tatter leaf-Citrange stunt (Citrus tatter leaf virus-CTLV, syn. *Apple stem grooving capillovirus*)

The disease is present in California and has the potential to cause significant economic damage due to the extensive use of the tristeza tolerant trifoliate and trifoliate hybrids (i.e. citrange) rootstocks that are sensitive to tatter leaf. *The virus causes bud union crease on trees growing on sensitive rootstocks which results in stunted, chlorotic trees.*

Veinenation-Woody gall (unknown, probable Luteovirus)

Naturally spread by aphids (same species as tristeza). The disease is endemic in California. It is not considered commercially important except when severe galling occurs on young trees budded on rough lemon rootstock.

POTENTIAL EXOTIC DISEASES IN CALIFORNIA

There are two major factors that have kept the California citrus industry relatively free of major citrus diseases. 1. The Federal regulation that forbids the introduction of any citrus propagation material in the United States unless under quarantine and 2. The decades old active disease testing programs at the quarantine and variety introduction level (i.e. Citrus Clonal Protection Program) as well as the CDFA registration program for nursery owned budwood and seed source trees. These two factors are applicable to all the following diseases. Additional regulations, based on the characteristics of the pathogen and vector of diseases, should be formulated.

Citrus canker –This is a major disease of citrus and is caused by the bacterium *Xanthomonas citri* (syn. *X. campestris* pv. *citri* or *X. axonopodis* pv. *citri*). This disease is currently not present in California; however, it is widespread in Florida and in many other citrus-producing countries around the world. Once established in an area, eradication is impossible. Efforts to manage the disease are continuous through the use of multiple copper applications and possibly with the use of antibiotics during the growing season. The most critical period is for fruit infection in the first 90 days after petal fall. Leaves, stems, and fruit become resistant as they mature. High wind, rain storms are conducive for disease development. Regulatory needs include maintaining quarantines and preventing fruit shipments from canker-infested areas to citrus-producing areas. Registration of antibiotics is also needed for emergency responses to any potential outbreak and evaluation of new ways to manage the disease.

Huanglongbing-HLB (*Candidatus Liberibacter* spp.)
Naturally spread by psyllids. Currently present in the USA, in the Asian Citrus Psyllid (Diaphorina citri). Huanglongbing is probably the most devastating disease of citrus ever to enter the United States (is currently found in Florida). The HLB infected trees (all kinds of citrus) are dying within a few years while fruit yield and quality are diminished. The pathogenic bacteria and the psyllid vectors have not yet been identified in California. The psyllid vector is present in Florida, Texas, Hawaii, and northern Mexico and most recently in California and Arizona. Early detection and eradication of HLB-infected trees and psyllid vector is going to be crucial for the survival of the California citrus industry. Representatives of the California Department of Food and Agriculture (CDFA) are involved in conducting surveys in cooperation with representatives of the California Citrus Research Board for the disease and vector in conjunction with the citrus canker survey.

Federal regulations forbid the movement of any citrus or ornamental plants of the Rosaceae family from Florida to California. Preliminary data from two independent labs indicate seed transmission of the disease. These findings triggered the federal regulation of the up to now free movement of citrus seed. Additional regulatory measures are necessary: 1. Banning of curry leaf shipments or any other HLB and psyllid host plants and plant parts from Hawaii or other states into California or via California ports and airports for other states. So far there have been three interceptions of the psyllid vector in California airports from such shipments. 2. Closer monitoring of electronic sales of citrus and citrus-family plants.

In the fall of 2007 USDA SITC personnel discovered several transactions of citrus plants sold to individuals in California by Florida sellers via the internet. Educational programs are also necessary for growers and home owners for the disease and vector threats and identification. Immediate research needs include: 1. The isolation and cultivation *in vitro* of the pathogenic agent or agents, 2. The development of a rapid, economic and reliable diagnostic technique for field surveys, and 3. The development of control, chemical and biological, strategies of the psyllid vector.

Citrus variegated chlorosis – CVC (*Xylella fastidiosa* pv. citri)
Naturally spread by several species of sharpshooters. Citrus variegated chlorosis can become a very important limiting factor in citrus production, as it is currently in Brazil. All citrus cultivars are susceptible and while the disease is rarely lethal, the produced fruit is unsuitable for the fresh or juice market. Seed transmission of the disease has been proven. The general federal regulation stands well in this case. Research needs include: 1. A diagnostic protocol capable of distinguishing the CVC causing pathovar from pathovars causing other diseases, such as Pierce's disease and almond leaf scorch, and 2. Efficient control strategies, chemical and biological, for the sharpshooter vectors.

Sudden death (unknown, probably Tymovirus and/or CTV)
Natural vectors are most likely involved but have not yet been identified. The disease has already killed more than a million trees in Brazil. Similar to CTV, there is a quick decline of sour orange rootstock, this disease kills trees growing on Rangpur lime and Volkamer lemon. Rootstocks such as Cleopatra mandarin, Sunki mandarin, trifoliate and trifoliate hybrids are tolerant to the disease and are used as alternative rootstocks in the diseased orchards in Brazil. The general federal regulation forbidding the introduction of citrus propagative material into the United States, unless under quarantine, stands well. Research needs include: 1. The full characterization of the pathogenic agent and its natural vector which will, 2. lead to the development of proper diagnostic protocols.

Blight (unknown, graft transmissible-root grafts)
The disease is one of the most economically important diseases in Florida and Brazil costing over $100 million annually in tree losses. The blight infected trees appear permanently wilted with a declining canopy and with small off color leaves and twig dieback. This appearance is due to the formation of lignin like plugs in the xylem system which fails to transfer water from the roots to the canopy. All citrus cultivars are susceptible to the disease with those of rough lemon, Rangpur lime, trifoliate and trifoliate hybrids being especially susceptible. Similar to other exotic diseases, the general federal regulation is well placed. Priority research needs are the full characterization of the causal agent of the disease.

Leprosis (*Citrus leprosis rhabdovirus*, cytoplasm & nucleus)
Naturally spread via mites of the genus Brevipalpus sp. (Flat mite, present in California). Leprosis disease induces severe lesion type symptoms on citrus leaves, twigs and fruit primarily on sweet and sour orange as well as mandarins. The disease can cause extensive crop losses (yield and quality) and tree debilitation. The biggest challenge for the control of this disease is the mite vector. Chemical control for mites is limited and the insect protective structures currently used in the California citrus budwood certification scheme are not mite proof. The federal regulations for budwood movement are well placed, but since fruit may also serve as a source of inoculum or virus carrying mites, it needs to be regulated as well. Research should be directed toward the development of rapid, economic and efficient diagnostic techniques for both the cytoplasm and nucleus type of the virus. Biological and chemical control methods for the mite vectors are also desirable research areas.

RESEARCH NEEDS – PRE-HARVEST DISEASES

1. **Important Research Needs:**
   a. **Armillaria root rot**
      - Biological & chemical controls for Armillaria (tree injections)

   b. **Septoria spot**
      - Need more research on new formulations of copper and alternatives to copper and zinc products (phytotoxicity is an issue with copper)
      - Need new postharvest treatments and registrations

   c. **Phytophthora root rot**
      - Berming/Mounding and its effectiveness

   d. **Dry root rot**
      - Need for further basic research on the biology and epidemiology of dry root rot. Specifically, predisposition factors that lead towards disease.

   e. **All diseases**
      - Fungicide resistance management especially when same tools become available for both pre and postharvest use. Example: Penicillium fruit decays.

   f. **Botrytis rot**
      - Fungicides needed as alternatives to copper (Fungicides that have been identified as having different modes of action as compared to other registered pre-and postharvest fungicides)

   g. **Citrus canker**
      - Improved detection systems
      - Improved regulatory standards must be established and maintained
      - Antimicrobial research – Registration of antibiotics such as streptomycin.
      - Development of resistant varieties.
      - Cultural practices to minimize conditions for infection such as wind breaks, etc.

   h. **HLB** (Huanglongbing Disease)
      - Compare to task force report
      - Molecular sequencing for improved identification of the pathogen
      - Evaluation of host resistance in citrus cultivars
      - Evaluation of antimicrobials
      - Evaluation of cultural practices such as vector trap crops, biological control of the vector, etc.

   i. **Citrus variegated chlorosis**
      - A virulent, citrus strain of *Xyella fastidosa*
      - Vector control/identification is needed
      - Improved detection systems
      - Antimicrobial research needed
      - Host resistance evaluations needed
      - Evaluation of cultural practices such as vector trap crops, biological control of the vector, etc.

   j. **Black spot** (Does not occur in US)
      - Continued investigations of management practices worldwide

   k. **Leprosis** (Does not occur in the US)

2. **<u>Important Educational Needs:</u>**
   - Irrigation: Alternate row, middle irrigation (Phytophthora)
   - Resistance management when same tools become available for both pre and postharvest use on fungal diseases.
   - Reference and list i.e.-task force, importing plants, fruit, seed, Citrus Research Board (CRB), California Department of Pesticide Regulation, public and growers, training within industry, landscapers, pest management professionals, border issues, i.e.-can't import, etc.
   - General education section :
     - General awareness of exotic diseases, emphasis on citrus canker and HLB, these two are the critical ones, (use examples where there are immediate threats)
   - Develop statewide educational seminars/programs for exotics (symptoms, occurrence and threat)
     - Special emphasis on citrus canker and HLB/psyllid Hawaii (need public awareness of threat to citrus industry)
     - Coordinate with UC, state, federal ,industry programs and international programs such as Mexico.
   - Statewide educational programs
     Targets: growers, public, pest management and landscape professionals (PCAs)

3. **<u>Important Regulatory Needs:</u>**
   - Expedite registration of Topsin-M* (since registrant isn't going to pursue this registration, need to identify alternate registrations of this active ingredients)
   - APHIS attention to detection and exclusion at the border for imported plants or fruits with emphasis on contiguous countries such as Mexico.
   - Exotic diseases-should reference specific guidelines and documents (for example-HLB task force)
   - Coordinate emergency response registration of identified pesticides (example streptomycin for citrus canker)
   - Pursue registration of alternatives for copper based materials
   - Educate regulators on products being used in other countries
   - USDA IR4 – studies to support full registration – coordinate minor use registration for citrus antibiotics, etc.

POSTHARVEST

De-greening and delaying fruit ripening in postharvest storage

Plant growth is regulated by naturally occurring growth regulators that act as hormones. To change the plant's physiology, synthetically produced plant growth regulators are commonly applied to certain agricultural crops. Selected plant growth regulators may have an indirect effect on the plants, susceptibility to postharvest decay caused by opportunistic pathogens. Ethylene gas applications to stored fruit are used to ripen fruit and this treatment may increase the susceptibility to decay. Conversely, any treatment that delays plant senescence will not only delay ripening, but may reduce susceptibility to those pathogens that favor senescent tissues for infection. For example, postharvest treatment of lemons with gibberellic acid reduces ethylene production, delays ripening, and consequently delays the onset of sour rot caused by *Geotrichum citri-aurantii*. In the packing house 2,4-D *is used on lemons to keep the buttons alive and healthy and to prevent abscission of lemon fruit buttons and thus prevent the development of *Alternaria rot*. Details are available for this use of 2,4-D*™ (AMVAC Chemical Corporation).

Disease Control During Postharvest Storage

1. **Pre-harvest practices for postharvest disease management.** The incidence of postharvest diseases can be reduced with integrated pre-harvest cultural and chemical practices that minimize injuries and protect fruit, respectively. Any handling practice that prevents wounds from occurring can help to reduce decay. Insect management can be an effective approach to reduce fruit injuries and subsequent decays of citrus. Fungicides available include Abound *(azoxystrobin) for management of *Penicillium*, *Alternaria* and *Colletotrichum* fruit diseases of citrus and Headline (pyraclostrobin) for the management of Alternaria. Pre-harvest air-blast applications of Abound can help to reduce decay losses from clear rot (i.e. pre-harvest *Penicillium* decays). Postharvest *Penicillium* decays (e.g., green and blue mold) have not been evaluated for fruit treated with Headline* preharvest.

2. **Truck or bin drenches.** Postharvest drenches of harvested fruit in the field have been effective in reducing *Penicillium* decays of early-harvested fruit that will be de-greened. For this, both thiabendazole* and imazalil* have been effective. Early season fruit may be injured by drenches from either fungicide. Although some treatments have been effective, some have increased incidence. Emphasis should be placed on correct concentrations of fungicides and effective sanitation programs to reduce decay and prevent the development of resistance in pathogen populations.

3. **Postharvest applications of sanitizers and fungicides.** Sanitation treatments such as hypochlorous acid (sodium hypochlorite) and peroxyacetic acid* (PAA) are used to reduce the inoculum levels of fruit pathogens, especially *Penicillium* and *Geotrichum* species. Water used to wash fruit that does not contain a sanitizing agent can be contaminated with spores of these pathogens and effectively inoculate fruit with decay organisms.

*Other trade names may apply

Fungicidal compounds including o-phenylphenol thiabendazole*, azoxystrobin*, fludioxonil*, pyrimethanil*, and imazalil* are also used to prevent infections of fresh injuries by P*enicillium* species. Sodium o-phenylphenol* (SOPP) generally does not penetrate the rind tissue of the fruit to any effective degree. Thus, these treatments must be applied before fungal growth develops into the wounded tissue. Fungicides such as thiabendazole* (TBZ) and imazalil can penetrate a short distance into the rind and button of the fruit and can prevent the development of decays after an infection period. Imazalil* is particularly effective at preventing sporulation of *Penicillium* species on decaying fruit. For sporulation control, fludioxonil* and azoxystrobin* are effective, whereas pyrimethanil* has limited activity. (Azoxystrobin* is expected to be available in California in 2009.) All three have been completely characterized. All the new fungicides, as well as the previously registered imazalil* and TBZ, are single-site mode of action products which increases the likelihood of resistance development. Use, for the newer fungicides, is limited due to the lack of MRLs in export markets.

- TBZ has high residue tolerances and does penetrate fruit rind tissues
- Imazalil* does have registration review issues because it is a listed carcinogen, but there is a need for continuing its registration as an integrated treatment with newer materials
- Populations of Penicillium spp. may develop resistance from the use of all single-site mode of action fungicides.
- All new fungicides as well as existing materials have a single-site mode of action.
- For sporulation control, azoxystrobin* and fludioxonil* are effective, whereas pyrimethanil* has limited activity.

Summary of Management Practices for Major Postharvest Decays in California:

***Penicillium* decays** (*P. digitatum, P. italicum, P. ulaiense*):

- Sanitation treatments (e.g. chlorine, PAA) reduce inoculum levels and help prevent the spread of decay.
- Registered fungicides include SOPP, TBZ, fludioxonil*, pyrimethanil*, azoxystrobin*, and imazalil*. Planned registrations include propiconazole*.
- Heat treatments of fruit are phytotoxic and only slightly to moderately effective in reducing decays.
- Irradiation has been fully evaluated and has been proven to be ineffective; it alters fruit surface integrity, causing fruit softening and pitting at doses that control decay.
- Sanitation to minimize spore contamination in packing houses is critical for an effective decay control program. It reduces inoculum levels and helps prevent the spread of decay and/or disease.
- Bio-Save 10 LP* is registered for managing green mold (*Penicillium digitatum*), blue mold (*Penicillium italicum*) and sour rot (*Geotrichum citri-aurantii*) on citrus.
    - First generation biological control products were thoroughly evaluated in the 1990s, and to date these and later products have shown only minimal to inconsistent control and none have been widely adopted.

*Other trade names may apply

Green Mold/Blue Mold

- Cultural: Prevent injuries
- Biological:
  - Treat with Bio-Save products (*Pseudomonas* strain), which acts as an aid, and is registered but cannot be used as a stand alone due to inconsistent performance.
  - Messenger*, an elicitor of natural pathogen resistance in plants, is registered for use before harvest, but it did not effectively control subsequent postharvest decay by the green mold pathogen, *P. digitatum.* Ineffective and not widely used.
- Chemical:
  - Sanitation: Physically remove damaged/decayed fruit.
  - Chemical sanitation: (including wash water and direct fruit contact products)
    - Wash with chlorine products such as sodium hypochlorite. Used as a general sanitizer but not as a stand-alone.
    - Ozone: Its effectiveness in aqueous systems has been poor under commercial, however, a low,controlled concentration of ozone gas in storage reduces sporulation and minimizes ethylene gas.
    - Chlorine dioxide
    - Peracetic acid* (PAA)
  - Equipment sanitation:
    - Quaternary ammonium.
    - Wash with chlorine products or other oxidizing products such as chlorine dioxide.
    - Formaldehyde also efficacious but has worker safety issues.
    - See overview of sanitation treatments Attachment A
  - Fruit protectants:
    - SOPP (sodium-o-phenylphenol*). Should not be used as a stand-alone treatment. Serves the purpose of controlling wound-site but not overall control. End up with decay if used as a stand-alone. Wash treatment used as an "in-line" process. Essential to control pH within a very narrow range to prevent fruit burn. Has a bad odor and there may be some disposal issues depending on locale.
  - Residual Fungicides:
    - **TBZ** (Thiabendazole) (Shield-Brite*): Used as an effective fungicide but has documented resistance. Can only be used as a stand-alone where resistance hasn't been detected. As season progresses, resistant populations build up and efficacy is reduced. Limited sporulation control.
    - **Imazalil** (Freshgard 700*): Similar to TBZ. Different class of chemistry and different mode of action. Effective sporulation control. Documented multiple-resistance between (up to) three classes of fungicides with three different modes of action; i.e. SOPP, TBZ, and Imazalil (and combination thereof).
    - **Pyrimethanil** (Penbotec 400SC*): New postharvest fungicide with no known field resistant populations of *Penicillium* spp. Different class of chemistry and different mode of action. One formulation with imazalil provides effective sporulation control. U.S. and Codex MRLs are now approved.

*Other trade names may apply

- **Fludioxonil** (Graduate*): New postharvest fungicide with no known field resistant populations of *Penicillium* spp. Different class of chemistry and different mode of action. US and Codex MRLs are approved.

- **Azoxystrobin** (Abound*): New postharvest fungicide with no known resistant populations of *Penicillium* spp. Different class and different mode of action (Qo Iinhibitor)from other postharvest fungicide. US and Codex MRLs are approved. California EPA approval for use is expected in November 2009

- **Fludioxonil/Azoxystrobin** (Graduate A+*) New postharvest pre-mixture of two fungicides with no known resistant populations of *Penicillium* spp. Two different classes with different modes of action from other postharvest fungicides will help to reduce the potential for selecting resistant populations.

- **Pyrimethanil/Imazalil** (Philabuster 400SC*): New postharvest pre-mixture of two fungicides with no known resistant populations of *Penicillium* spp. to pyrimethanil.

Sour Rot

- Cultural: Prevent injuries. Use of PGRs such as gibberellic acid (delays senescence).
- Biological Controls: None currently available.
- Chemical:
  - The fungicide SOPP (sodium-o-phenylphenol*): is moderately effective, provides less than 50% control.
  - Sanitation: physically remove damaged or decayed fruit.
    - Planned registration of propiconazole. Is highly effective.
  - Chemical sanitation (including wash water and direct fruit contact products):
    - Wash with chlorine products such as sodium hypochlorite. Used as a general sanitizer but not as a stand-alone.
    - Ozone: its effectiveness in aqueous systems has been consistently poor under commercial conditions; however, a, low controlled concentration of ozone gas in storage reduces sporulation and minimizes ethylene gas.
    - Chlorine dioxide
    - Peroxyacetic acid (PAA)
  - Equipment sanitation:
    - Quaternary ammonium compounds
    - Wash with chlorine products
    - Chlorine dioxide
    - Formaldehyde also efficacious but has worker safety issues
    - See overview of sanitation treatments Attachment A
  - Other sanitation: Irradiation has been fully evaluated and has been proven to be ineffective, alters fruit surface integrity.

***Other trade names may apply**

Minor decays – *Alternaria* (sanitation programs as above)
Can be problems in some years but not a consistent problem.

- Cultural: Use of 2,4-D* on lemons to maintain integrity of button, used postharvest, to maintain tree vigor.

Brown Rot (sanitation programs as above)

- Cultural: Some literature refers to use of hot water treatment although oftentimes results in phytotoxicity. Fruit damage is so extreme that treatment is not practical.

Stem End Rot
Primarily seen in desert lemons

- Chemical: TBZ* (very effective)

Cottony Rot, Trichoderma, Botrytis
Fairly regional/found on coast

- Chemical: TBZ* - effective treatment ,however, quiescent infections may occur in the field for which TBZ* may be of limited effectiveness.

Septoria Spot

- Chemical:
    - TBZ* (moderately effective)
    - Fludioxonil* (MRLs: US – 10 ppm; Codex – 7 ppm)
    - Azoxystrobin* (MRLs: US – 10 ppm; Codex – 15 ppm)

2. Important Research Needs:

- Resistance management tools ranging from sanitation to residual fungicides with new modes of action.
    - Detection and monitoring programs
    - Quantification of resistance levels in individual packing houses
    - Mixture of fungicides with GRAS sanitizers, such as potassium sorbate, to minimize development of fungicide resistant spore populations.
    - Formulations that are alternatives to formaldehyde.
- Due to lack of export MRLs, new postharvest fungicides have not been tried.
- Phosphites – need continued research for pre-harvest, for postharvest control.
- Support registration of azoxystrobin* (Syngenta) for *Penicillium* decays.
- New strategies for Sour Rot control (other countries have residual fungicides available for use that are not available in US). Guazatine* materials have multiple active ingredients which EPA has made impossible to register (need toxicology data for each a.i. within each product). Not cost effective for registrant to conduct studies.
- Sanitation treatments as supplements or alternatives to formaldehyde.
- Continue the development of new fungicides.
- Need good field methods for developing some of these new compounds.

*****Other trade names may apply

3. *Important Regulatory Needs:*

- Need expedited registration of propiconazole*
- Need MRLs for all new fungicides in export market countries including food additive clearances in Japan
- Registration of potassium sorbate*

4. *Important Educational Needs:*

- Need for instructional video detailing proper Postharvest handling of fruit. Focus on prevention of injuries, temperature management, treatments, washes, etc.
  Need for educational materials (for packing house managers and crew) regarding the use of new materials and strategies for resistance management, overuse, rotation of chemistries, etc. Currently, guidelines are being established for the industry.
- Need for growers, continued education on the value of use of PGRs on lemons to delay senescence/color in order to better respond to market supply and demand.

*****Other trade names may apply

MANAGEMENT OF PRODUCTION CITRUS

Periods of concern:
Prebloom (Feb-Mar)
Bloom (Mar-Apr)
Petal fall (April-May)
Summer season (June-September)
Pre-harvest-Harvest (Sept-January)
Postharvest

General Research Needs for Production Citrus

1. Long term impacts of various types of chemical control – shifts in pest and natural enemy populations due to pesticide use patterns.
2. Development of IPM programs for organic orchards.
3. Improved spray technology to more effectively control citrus pests while minimizing drift.
4. Pesticide resistance management.

Citrus Peelminer (summer, pre-harvest, harvest, postharvest) *Economically important primarily in the desert and San Joaquin Valley*

- Cultural controls: Orchard sanitation which includes sucker removal and a clean harvest. Remove all fruit. Clean orchard floor. Planting Bt cotton reduces the impact of that crop on citrus. High pressure washer minimizes the risk of shipping live peelminer to other countries.
- Biological controls: Native parasites are weakly controlling this pest in the San Joaquin Valley. A non-native (*Cirrospilus*) is presently being released and others are being researched. Avoid broad-spectrum pesticides to preserve natural enemies.
- Chemical controls: Insecticides are relatively ineffective in stopping citrus peelminer infestations.

Citrus Peelminer research needs:

- Continue research efforts on biological control of citrus peelminer. Movement of parasites between citrus leafminer and citrus peelminer and other hosts.
- Importation of parasitoids from other areas such as Mexico.
- Continued research on pesticide controls for citrus peelminer, including the impact on natural enemies. (especially Micromite* and oil).
- Pheromone disruption and monitoring: need a better lure.
- Postharvest control for export markets.
- Monitor for the appearance of the Mexican strain in other regions of CA.
- Monitoring for the presence of other strains that might arrive in California.
- Continue to evaluate varietal susceptibility of citrus to citrus peelminer.

*****Other trade names may apply

Citrus Leafminer (summer, pre-harvest-harvest) *Primarily a pest of new plantings and perhaps mature lemons on the coast.*

- Cultural controls: Manipulating flush to minimize the period of flushing (timing of nitrogen and pruning). Varietal differences.
- Biological controls: Native parasitoids exist and exotics are being considered. Parasitism lags behind introduction of CLM in new regions.
- Chemical controls: Limited to Admire*, Assail*, Neem*, Oil, (Agri-Mek* in bearing citrus), Success* and Delegate* in bearing citrus, 24C for Intrepid on nonbearing citrus.

Citrus Leafminer research needs:

- Additional insecticides specific to Lepidopteran pests and their impact on biocontrols to rotate and reduce resistance.
- Study the use of various chemicals for other pests and simultaneous control of CLM.
- Yield studies, especially on lemons on the coast to determine the impact of citrus leafminer on yield.
- Manipulation of flushing to reduce CLM densities.
- Low rates of oil in the nursery (especially the highly refined oils).
- Phenology of the CLM in the various regions of California.
- Pheromone disruption.
- Studies of native natural enemies.
- Parasitoids imported from other regions and level of cross-over to the citrus peelminer.

Light Brown Apple Moth (bloom, petal fall) Bay area and the coast.

- Cultural controls: Making sure no leaves are in bins transported from infested to uninfested regions.
- Biological controls: Not yet present on citrus.
- Chemical controls: Not yet present on citrus.

LBAM research needs:

- Basic biology, monitoring, biological control and chemical management tactics for citrus.
- Research will be critical as soon as LBAM reaches citrus (monitoring tactics, pheromone disruption, and chemical control).
- Spinosad works, but how long before LBAM develops resistance to this product?

Worms (bloom, petal fall) Worms are currently minor or sporadic pests because the shift from OPs and carbamates to Spinosad* for citrus thrips and pyriproxyfen* for California red scale since 1998 has favored natural enemies and reduced worm problems in general. Spinosad* has activity against worms and so treatments for citrus thrips coincidentally reduce worm populations.

- Citrus cutworm: sporadic pest, fairly easily reduced by Bt prior to petal fall and Success* or Success* in combination with Baythroid*, Danitol* or Lorsban* at petal fall applied for citrus thrips.
- Fruittree leafroller in Valencias (possibly) Biological controls: No commercial natural enemies available. Some native natural enemies exist. Growers should avoid broad-spectrum insecticides when possible.

*Other trade names may apply

- Amorbia (most commonly found when grown near avocados). *Trichogramma* wasp releases are an effective control.
- Orange tortrix: Biological: No commercial natural enemies available at this time. Some native natural enemies exist; avoid broad-spectrum insecticides.
- Worm Chemical controls:
  Bt is effective on small instars. Timing is important and warm weather can improve efficacy of this product because the larvae are more actively feeding.
  Kryocide* is also effective on small instars. Timing of application is important. Warm weather improves efficacy because the larvae are more actively feeding.
  Lannate*, Lorsban*, and Dibrom* are occasionally used; however, they are much more disruptive to natural enemies and there are label restrictions associated with use near bees.

  At petal fall: If worms are present at the time of citrus thrips treatment, Baythroid*, Danitol*, Dimethoate*, or Success* will simultaneously control young instars of both species unless citrus thrips resistance is an issue.

Worm research needs:

- Watch for new species or strains moving in from other crops, other countries.

<u>Citrus red mite (prebloom, bloom, petal fall, fall)</u> *(typically not a problem in coastal areas; can be a major problem in the southern California interior in the fall with Santa Ana winds, leading to leaf drop, can be a problem in the SJV from prebloom through May)*.

- Cultural controls: Implement dust reduction measures and proper irrigation of the trees.
- Biological controls: Predatory mites and virus during the hot periods are major control factors. Methods include avoidance of broad-spectrum pesticides to encourage natural enemies (predatory mites/beetles).
- Chemical controls: Oil is moderately effective. Efficacy is rate dependent. Oils are less expensive than miticides. The use of VOC generating materials is gaining the attention of the Air Resources Board. This is definitely an emerging issue that needs to be watched. Often the rate of oil in the citrus thrips treatment is increased from 0.5% to 1.4% to help control red mite. Efficacy is rate-dependent.
  - <u>Nexter*</u>: is sometimes used. Nexter* is more efficacious while being less selective, i.e. more disruptive to beneficials. Efficacy is rate dependent.
  - <u>Omite*</u>: can be used in warm weather. Omite* is more compatible with natural enemies; however Omite* has a long REI and is a minimal exposure pesticide (MEP).
  - <u>Vendex*</u>: can be used in warm weather. Vendex* is more compatible with natural enemies than other registered miticides.
  - <u>Kelthane*</u>: can be used in warm weather. Kelthane* is harsh on predatory mites and there are problems with resistance.
  - <u>New materials</u> – Fujimite*, Kanemite* (some varieties), Envidor*, Onager*.
  Many more miticides will soon be registered (Zeal*, Acramite*, Oberon*, Ultiflora* have nonbearing citrus registrations).

*Other trade names may apply

Citrus red mite research needs:

- Significance of citrus red mite for providing food for predatory mites so that the predators are more abundant during citrus thrips season.
- Long-term effects of miticides and insecticides (for other pests) that cause secondary outbreaks of mites or other pests.
- Varietal susceptibility to citrus red mite (new mandarin varieties).
- Impact of growth management (irrigation, pruning, etc.) on citrus red mite populations.

Spider mites

Two spotted spider mite (*Infrequent pest).* **Yuma spider mite (fall)** *Primarily the Coachella and southern SJV* **Texas citrus mite (fall)** *Primarily Coachella and southern SJV.*

- Cultural controls: Methods include dust reduction and proper irrigation.
- Biological controls: Include avoidance of broad-spectrum insecticides to encourage natural enemies (predatory mites/beetles).
- Chemical controls: Oil is moderately effective. Efficacy is rate dependent. Oils are less expensive than miticides. The use of VOC generating materials is gaining the attention of the Air Resources Board. This is definitely an emerging issue that needs to be watched.
- Oils are moderately effective. Often the rate of oil in the citrus thrips treatment is increased to help control two-spotted spider mite. Efficacy is rate-dependent.
  - Nexter*: (a small amount of this product is used). Nexter* is fairly efficacious and less selective but disruptive of natural enemies. Efficacy is rate dependent.
  - Omite*: can be used in warm weather. Omite* is more compatible with natural enemies, however Omite* has a long REI and is a minimal exposure pesticide (MEP). There are problems with resistance to Omite*.
  - Vendex*: can be used in warm weather. Vendex* is more compatible with natural enemies than other registered miticides. There are problems with resistance to Vendex*.
  - Kelthane*: can be used in warm weather. Kelthane* is toxic to predatory mites and there are some problems with resistance.
  - New materials – Fujimite*, Kanemite* (some varieties), Envidor*, Onager*.

  Many more miticides will soon be registered (Zeal*, Acramite*, Oberon*, Ultiflora* have nonbearing citrus registrations).

Spider mite research needs:

- Biological controls: evaluate the significance of natural enemies for Texas citrus mite and Yuma spider mite.
- Varietal susceptibility, especially mandarins.
- Basic biology of Texas citrus mite and Yuma spider mite.
- Define distribution and extent of damage in new regions for Texas citrus mite and Yuma spider mite.

*****Other trade names may apply

Citrus flat mite/Brevipalpus (year round) *Potential vector of leprosis and will become a significant problem if that disease arrives in CA.*

- Cultural controls: avoid damage of fruit.
- Biological controls: none known to be effective.
- Chemical controls: Many miticides are effective and sulfur is a common treatment, but sulfur is disruptive to natural enemies.

Brevipalpus research needs:

- Distribution of the species in California citrus and ornamentals.
- Capability of the various Brevipalpus species in vectoring leprosis.
- Study why mites appear around damaged areas of fruit.
- Need for a systemic miticide.
- Need a study on the long-term effects of various miticides (and insecticides) on Brevipalpus populations.
- Biological control study – what preys on flat mite?

Broad Mite: (year round) *(coastal lemons, especially organic orchards)*.

- Cultural controls: Dust reduction and proper irrigation.
- Biological controls: Maintain control of ants.
- Chemical controls:
  Agri-Mek* + oil: very effective (although resistance may be developing), expensive.
  Sulfur: very effective, better with warm temperatures. Can be phytotoxic in hot weather. Do not use with oil.
  Lorsban* + oil: very effective. Not preferred timing. Can cause fruit ridging.
  Nexter*: effective.

Broad mite research needs:

- Association of broad mite with ants and mealybugs.
- Long term effects of chemical control – shifts in pest populations due to pesticide use patterns.
- Better monitoring technique needed.
- Development of a control program for organic orchards.

Citrus Bud Mite:

- Cultural controls: None available.
- Biological Controls: None available at this time.
- Chemical controls: Oil somewhat effective, need good coverage. Expensive. Research has shown that control with oil may not be economic (negative impacts of oil on yield don't improve productivity sufficiently to offset the cost of treatment).
  Agri-Mek* + oil: somewhat effective, expensive.
  Sulfur: somewhat effective, better with warm temperatures. Can be phytotoxic in hot weather. Do not use with oil.
  Lorsban* + oil: somewhat effective. Not preferred timing. Can cause fruit ridging.
  Nexter* needs to be looked at.

*Other trade names may apply

Citrus bud mite research needs:

- Impact of low rates of oils as additives, how oils affect yield and if control is economic.
- Demonstration that there may be little economic advantage to treating for citrus bud mite.
- Test new pure oils to determine if they reduce yield impact and improve control.
- Screen new miticides for citrus bud mite – need more effective materials (Envidor, Fujimite and others).

<u>Silver Mite (bloom)</u> *(called citrus rust mite on oranges and grapefruit, called silver mite on lemons (coast and in Blythe)*

- Cultural controls: None available.
- Biological Controls: None available at this time.
- Chemical controls:
- Oil not effective.
  Agri-Mek* + oil: effective, expensive.
  Sulfur: effective, better with warm temperatures. Can be phytotoxic in hot weather. Do not use with oil.
  Lorsban* + oil: effective. Not preferred timing. Can cause fruit ridging.
  Nexter* needs evaluation.

<u>Citrus Thrips (petal fall)</u>

- Cultural controls: none currently developed.
- Biological controls: Preserve natural enemies such as predatory mites by avoiding broad-spectrum insecticides. Use of "soft" pesticides including Success*, Delegate*, Agri-Mek* and Veratran*.
- Chemical controls:
  Agri-Mek *(and generics): tends to preserve natural enemies, is used with a small amount of oil to increase translaminar movements into leaves and fruit, but its relatively high cost (is coming down with the appearance of generics) in contrast to effective alternatives (especially Success*) have limited its use by California growers for citrus thrips control.
  Veratran*: tends to preserve natural enemies, is a stomach poison, and is less effective than Success* or Agri-Mek*. Veratran* is made from the ground seeds of a lily-like plant that grows in Venezuela and contains 0.2% alkaloids as the active ingredient. Efficacy is increased by lowering water pH to 4.5 prior to adding Veratran D* to the spray tank. Sugar (5-10 lbs/a) or cane molasses (1-2 gal/a) are usually added to Veratran D* (even though the product is 80% sugar to begin with) to increase efficacy.
  Success*: tends to preserve natural enemies and is used with a small amount of oil to increase translaminar movement into leaves and fruit.
  Broad Spectrum insecticides: Baythroid*, Danitol*, Dimethoate*, and Carzol*. Thrips have shown resistance to Baythroid*, Dimethoate* and Carzol* in some areas of California.
  Delegate*: similar chemistry to Success*, appears to have greater persistence; will likely replace Success*.
  Movento*: Newly registered and trials have shown good efficacy against citrus thrips and a high level of selectivity favoring natural enemies.

* Other trade names may apply

Citrus thrips research needs:

- Establish economic thresholds for citrus thrips with new and/or selective materials.
- Need to determine resistance levels in citrus thrips for new products and potential for cross resistance.
- New insecticides with different chemistry to control citrus thrips.
- Determine impact of new products on natural enemies and other pests such as katydids, worms.
- Examine the potential to manipulate flush or use mulches to reduce thrips populations.

Greenhouse Thrips: *Generally a coastal problem in the spring, summer and fall. Becomes a problem where broad-spectrum OPs were not used. Primarily a pest in organic situations. Heavy with high humidity.*

- Cultural controls: Harvest early.
- Biological controls: None commercially reared because greenhouse thrips is a sporadic pest. *Thripobius semiluteus* is difficult to rear and thus too expensive. Some PCAs doubt its effectiveness.
- Chemical controls:
  Lorsban*: Very effective with good coverage.
  Malathion*: effective but is disruptive to beneficials.

Greenhouse thrips research needs:

- Non OP alternative insecticides.
- Other biological control agents.
- Varietal effects on late harvested fruit and clustered fruit where damage is the worst.

California red scale (prebloom, bloom, petal fall, summer, fall) *Under excellent biological control in southern California, except when disrupted by ants, dust, or pesticides. Under an annual eradication program in the Coachella Valley*.

- Cultural controls: Dust suppression.
- Biological controls: *Aphytis* wasp releases in the SJV are effective at a rate of 5,000/acre every two weeks until a total of 100,000/acre are released. Avoid broad-spectrum pesticide applications (OPs, carbamates, neonicotinoids, pyrethroids) which generally reduce or eliminate this natural enemy.
- Chemical controls: The period of May thru June is the first window for chemical treatments as the first generation of scale crawlers is emerging and settling down on leaves and twigs.

Organophosphate and carbamate treatments include Lorsban*, Supracide*, Sevin*, Esteem* or Applaud*. There are problems with red scale resistance to Lorsban*, Supracide*, and Sevin*. Efficacy of insecticides is influenced by resistance, spray timing, and spray coverage. The organophosphates (Lorsban* and Supracide*) and carbamates (Sevin*) are toxic to parasitic wasps. Efficacy of OPs and carbamates are improved if they are applied at the time of crawler emergence.

Insect growth regulators (Esteem* and Applaud*) are toxic to predatory beetles. Efficacy of insect growth regulators is improved if they are applied when 1st instar scale is white caps, just prior to molting. Growers generally avoid using insect growth regulators during the first generation of crawler emergence because they are toxic to Vedalia beetles and will disrupt cottony cushion scale biological control.

*Other trade names may apply.

Oil treatments may be used in the summer as dilute applications in well-irrigated orchards when temperatures are less than 95 degrees. Oils are relatively non-toxic to natural enemies because their residual activity is brief, except predatory mites.

Movento*: Registered and trials have shown good efficacy against California red scale and a high level of selectivity favoring natural enemies, making Movento* an excellent rotational insecticide for red scale control. Export MRLs are lacking.

- Postharvest: High pressure fruit washer. Works very well to reduce the effects of scale. Has reduced incidences of postharvest diseases and improves shine from wax application. Some problems are seen with early fruit. Cyanide used as a disinfestation treatment. Only one operator currently approved to fumigate using this material.

CRS research needs:

- Research on pesticide resistance in red scale (Esteem*).
- Effects of treatments for this and other pests on natural enemies.
- Movento* as a foliar systemic and the influence of treatment timing and water volume.
- Spray application equipment and methods to improve efficiency, delay resistance, minimize drift.
- New natural enemies needed for the desert area.
- Evaluate the effectiveness of exotic strains of natural enemies that may be better than current strains (improved climate matching; possible release of cryptic species identified using genetic methods).
- Effective replacement of VOC oils (citrus oils).
- Development of new types of sprayers/ more effective application.
- Import new parasitoids (foreign exploration).

Cottony Cushion Scale (bloom, petal fall, summer, pre-harvest, harvest, postharvest)

Under excellent biological control in southern California, except when natural enemies disrupted by ants, dust, or pesticides.

- Cultural controls: none.
- Biological controls:

Vedalia beetle and the *Cryptochaetum* fly are the most effective natural enemies of cottony cushion scale. In the SJV, it is critical that vedalia beetle be present during March – April to gain full control of cottony cushion scale. Vedalia beetles are not commercially reared. Growers find vedalia beetles in their orchards and move them to where they are needed. Esteem*/Applaud*, Admire*, Assail*, Baythroid*, Danitol*, and Provado*treatments are toxic to Vedalia beetle and so should be avoided if cottony cushion scale is present. CCS is emerging as a primary pest due to new insecticide registrations that disrupt Vedalia beetle.

Ants protect scale insect pests from parasites and predators and so ant control can help biological control be more effective. (The only registered product for the sugar-feeding ants is Lorsban* ground sprays).

- Chemical controls:

Supracide*: Is moderately effective against cottony cushion scale. Very toxic to most natural enemies except Vedalia beetle.

*Other trade names may apply

Malathion: Is moderately effective against cottony cushion scale. Very toxic to most natural enemies except Vedalia beetle.

Applaud*: Controls CCS very slowly but could be used under some circumstances because Applaud has IPM compatibility with natural enemies other than beetles.

- Postharvest: High pressure fruit washer. Works very well to reduce the effects of sooty mold on varieties of fruit that can tolerate pressure. Has reduced incidences of postharvest diseases and improves shine from wax.

Cottony cushion scale research needs:

- Research on mandarin susceptibility to CCS (varietal effects).
- Pruning as a cultural control method.
- Impacts of new pesticides on Vedalia beetle and *Cryptochaetum*.
- Time length of wraps on young tree trunks and the interaction with ants.
- Economic threshold for damage by CCS (impacts on sooty mold and yield).

Citricola scale (Prebloom, bloom, summer, fall):

- Cultural controls: None at this time.
- Biological controls: None reared by insectaries at this time except *Metaphycus helvolus* (inconsistent supply, expensive). Avoid broad-spectrum pesticides to preserve natural enemies.
- Chemical controls:

Lorsban*: Is the most selective insecticide available for citricola scale control because many natural enemies have developed resistance to Lorsban* and its persistence is relatively short. Under heavy spring population conditions, growers need to treat immediately to prevent sooty mold and yield reductions. However, treatments are not very effective at this time of year because the scale is large and located deep inside the tree canopy. When possible, treatments should be delayed until later in the year (Aug-Sept) for maximum toxicity to small nymphs on the outside of the tree or even later (October – November) to preserve natural enemies. Efficacy of treatments is influenced by weather, i.e. principally by temperature and moisture. Cool, wet springs and cool summers exacerbate the citricola scale problem. High heat in August/September reduces their numbers. Some late-season Lorsban* treatments are applied if weather is warm enough to reduce citricola, but avoid disruption of natural enemies. Lorsban* is not used December thru March because Lorsban* can cause ridging of fruit. Some populations of citricola scale in the San Joaquin Valley have developed resistance to Lorsban*.

Provado* and Assail*: These neonicotinoid insecticides are moderately effective against citricola scale. The disadvantage of these insecticides is that they are not accepted by some countries (lack of Codex residue tolerances) and they are fairly broad spectrum, killing most natural enemies. The advantages are that they have much shorter REI and PHI than Lorsban*, and they are more effective in the spring months. Efficacy of these insecticides is not temperature dependent.

Admire*: GWSS treatments with Admire* have had the benefit of reducing (but not eliminating) citricola scale populations.

- Postharvest: High pressure fruit washer. Works very well to reduce the effects of sooty mold on varieties of fruit that can tolerate pressure. Has reduced incidences of postharvest diseases and improves shine from wax.

***** Other trade names may apply

Citricola scale research needs:

- More research on selective citricola scale pesticide treatments.
- Alternatives to Lorsban 4 EC* because of VOCs.
- Alternatives to Lorsban* because of resistance.
- Methods to produce natural enemies cost effectively, use of alternative host insects and host plants; what levels of natural enemies are needed and which species are most effective at various times of the year.
- The effect of canopy management on citricola scale mortality during the summer.
- Efficacy of new highly purified oils.
- Import new parasitoids (foreign exploration).
- Economic threshold for damage related to sooty mold and yield.
- Proximity to urban areas and brown soft scale.
- How parasitoids and various species of ants interact with citricola scale.

Brown Garden Snail (prebloom, bloom, petal fall, harvest) *See restriction on distribution of Decollates.*

- Cultural controls: Skirt pruning. Snails attack fruit that is close to the ground. Skirt pruning helps to lift up the skirts so that snails reach fewer fruit.
- Biological controls: Move decollate snail (predatory snail) into the orchard. Spread of decollates throughout an orchard can require 5 years to complete. Chemical treatments for slugs are incompatible with decollates. Decollates are allowed in California in only 12 counties: San Bernardino, Riverside, Imperial, Orange, San Diego, Los Angeles, Ventura, Kern, Fresno, Madera, Tulare and Santa Barbara.
- Chemical controls:
  Metaldehyde.
  Sluggo* (iron phosphide).

Snail research needs:

- Does Sluggo* (and other products) work? Resistance? Timing? Attractant? Placement?
- What is causing decollate snail decline in many orchards? (Pathogens of decollates?)
- Mechanism of how decollates work – what stages of Brown Garden Snail they attack or is it interference?
- Methods for reintroducing decollates after they decline and preventing later decline.

Ants (petal fall, summer, pre-harvest, harvest)

- Cultural controls: Skirt pruning, trunk barrier.
- Biological controls: None available.
- Chemical controls:
  Lorsban* for sugar feeding black and gray ants.
  Abamectin*, Imidacloprid*, Clinch* and Esteem* ant baits for red ants. These treatments work best when ants are active which tends to be later in the season.
  Fall treatments sometimes use pre-emergent herbicides combined with Lorsban* to control the ants. Efficacy depends on warm temperatures and dry conditions.
  Liquid sugar bait toxicants: Tango* (methoprene), Gourmet* (boric acid), Vitis* (imidacloprid*).
  Bait stations: three are registered.

*Other trade names may apply

Ant research needs:

- Continue research to develop improved ant control systems or bait stations. Bait stations are needed for sugar-feeding ants (Argentine and native gray ants). There are problems associated with bait stations, i.e. economics and regulatory issues.
- How many bait stations are needed per acre and for how long? Versus populations of Argentine and other species of ants.
- Formulations and toxicant choice.
- Fipronil* is very effective and needs non food crop registration (may be okay in a bait).
- Need for surveys of ant species distribution.
- Monitoring methods for various ant species.
- Establish the impact of ants on natural enemies (especially minor species).
- How does controlling the pest influence ant problems?
- Impact of uncontrolled ants in neighboring orchards on bait station efficacy.
- Alternatives to Lorsban* for trunk/ground sprays.

Forktailed Bush Katydid (bloom, petal fall)

- Cultural controls: None available at this time.
- Biological controls: None except endemic egg parasitoids available at this time.
- Chemical controls:

  Bloom: Kryocide* is used, but is only effective on small instars when applied in warm weather. Micromite*: effective late bloom spray, takes about 10 days for katydid to molt and be affected.

  Petal fall: Tank mix a broad spectrum OP or pyrethroid with citrus thrips material. For example, low rates of organophosphate (Lorsban*, Dibrom*, Cygon*) or pyrethroid (Baythroid*, Danitol*) insecticides with Success* for thrips. At petal fall, there is a high risk of damage because katydids prefer to feed on young fruit and there may be larger instars that are harder to kill. Lorsban* registration is important to maintain because it is one of the most effective and selective insecticides for katydid control. Lorsban* can be used at extremely low rates (2-6 oz/acre) and quickly and effectively kill katydids. Many of the natural enemies in the San Joaquin Valley have resistance to Lorsban*.

  Delegate*: A new product for citrus thrips control whose impact on katydids is presumed to be good. Export MRLs are lacking.

Katydid research needs:

- There is a need to better understand endemic biological control of katydids and what materials cause disruption.
- Method of rearing parasitoids on artificial diet.
- Timing and effects of fall applications to control populations and reduce the impact the following spring.
- Evaluate microbial *Nosema** for control.
- Improved trapping/monitoring (Acoustic trap: attracts females).
- Movement between crops (plums, nectarines, peaches).
- Evaluate the effect of citrus thrips treatments of Delegate* on katydid populations.

*Other trade names may apply

Earwigs (prebloom, bloom, petal fall) Earwigs are an emerging pest problem in some areas of the SJV where organophosphates are no longer used. Earwigs cause damage to young trees by girdling them. They can attack the young fruit of mature trees.

- Cultural controls: no wraps, or early removal, skirting.
- Biological controls: none that we know of.
- Chemical controls: There used to be pomace baits with toxicants: carbaryl*, arsenic.

Earwig research needs:

- Basic biology and chemical control methods.
- Biological control studies.
- Need to screen pesticide products with bait attractants.
- Application methodology for young trees with wraps.
- Examine the efficacy of M-Pede* for earwig control.

Grasshoppers (emerge from pasturelands and migrate into citrus)

- Cultural controls: None at this time.
- Biological controls: *Nosema** bait.
- Chemical controls:
  Sevin***:** Sevin* can be an effective insecticide. The difficulty in using this product is that you must have a quick response, apply a high rate, and get good coverage since grasshoppers can arrive suddenly in large numbers.
  Micromite* can be used on adjacent pastureland to reduce the young instars. Does not work fast enough when grasshoppers get to the citrus, so is not suitable as a citrus treatment.

Grasshopper research needs:

- Basic biology and control methods, predicting economic infestations.

Diaprepes Root Weevil (currently only found in Southern California)

- Cultural controls: Exclusion.
- Biological controls: Three species of parasitoids imported from Florida but may not be adapted to CA interior conditions, attack egg stage. Nematode and Beauveria control for larvae appears only moderately effective.
- Chemical controls: Admire*, Micromite*, Talstar* barriers.

Diaprepres research needs:

- Parasitoids adapted to dry areas.
- Effective soil treatment for the larvae.
- Better traps.
- Economic thresholds for agricultural crops.
- Accelerate the development of pheromone traps – trap and kill technology.
- Host range and environmental range in California.
- Resistant rootstock research.

*Other trade names may apply

Bean Thrips (pre-harvest and harvest): *This pest presents an export problem for New Zealand and Australia.*

- Cultural controls: Reduce weeds, such as tree tobacco, that harbor bean thrips. Do not export fruit planted next to rangeland, beans or other host crops.
- Biological controls: None at this time.
- Chemical controls: Undeveloped at present.
- Postharvest: Warming up fruit before washing is being used but is of unknown efficacy. Extra inspection.

Bean thrips research needs:

- Evergreen*, ethyl formate* and Turbocide* and other postharvest control for bean thrips.
- Effect of normal cold shipment on thrips viability and ability to produce viable eggs.
- Evaluate insecticides that could be used in the field in the fall.
- Improve sticky card monitoring, fruit cutting in the field and packing house, warming eight hours before washing, phytosanitary inspection and either preclearance or inspection in Australia.
- Relationship between sticky card monitoring and level of thrips in the fruit and whether or not their use should be mandated.
- Automated Packinghouse monitoring of large amounts of fruit to detect the bean thrips – better nondestructive detection of thrips in the packinghouse in the fruit.

Fuller Rose Beetle: No longer a *Phytosanitary export issue for Japan* and so has become a minor pest for citrus.

- Cultural controls: Skirt pruning.
- Biological controls: None except endemic parasitoids at this time. Avoid broad-spectrum pesticides to preserve natural enemies.
- Chemical controls:
  Sevin*: works well; may need two treatments as beetles emerge over a long period of time.
  Kryocide*: works well; may need two treatments as beetles emerge over a long period of time.

Fuller Rose Beetle research needs:

- Yield impacts of Fuller rose beetle in citrus in sandy soils.

*Other trade names may apply

GWSS (prebloom, bloom, petal fall, summer, harvest)

- Cultural controls: None available.
- Biological controls: A combination of native and introduced parasitoids are helping to control GWSS in southern and coastal California.
- Chemical controls:

  Admire* (imidacloprid) for nymphs is generally 85% effective; however Admire* is disruptive to cottony cushion scale and reduces natural enemies. There are also label restrictions associated with the use of Admire* during bloom due to bee toxicity.

  Foliar treatment with Assail* may take place in March or in the fall. While Assail* is more effective and less expensive than Admire*, Assail* is also more disruptive to beneficials and only lasts one generation. Conversely, Admire* lasts 6 months, thereby covering 2 generations. Assail* also has label restrictions associated with its use in the presence of bees.

  There exist (in some areas) quarantine restrictions that prohibit the movement of fruit, after harvest, to non-infested areas.

  Fall pre-harvest treatments. Assail* has MRL problems but is an option for fruit exported to Japan, Korea, and Canada. Baythroid* is an option but has a limit of 6.4 oz per year. So if Baythroid* is used for citrus thrips (at the full rate) control, then Baythroid* can't be used for GWSS control.
- Postharvest: Evergreen* ultra low volume atomized space treatment. Kills adults. Only used in packinghouses. Only lasts 24 hours and requires extra inspection.

GWSS Research needs:

- Need a better understanding of the impact of the GWSS areawide programs on natural enemies. Research winter/fall treatments for GWSS vs. spring treatments (level of disruption of natural enemies).
- Find GWSS treatments that are more compatible with IPM.
- Effective treatments for organic citrus – organic groves serve as a reservoir for both GWSS.
- Continue research efforts on biological control of GWSS.
- Continue research to establish thresholds for GWSS treatment requirements. Population threshold for GWSS is zero in the eyes of the grape growers.
- Determining if parasitoids are effective in all areas of California.
- What level of GWSS reduction in citrus is a problem for grapes.
- Range expansion of GWSS and need for shipping restrictions within the state.
- Improved methods of rearing parasitoids.
- Everything changes if we get CVC in California (is now in Mexico) – resistant plant material, thresholds will become lower, more effective treatments will be needed.

*Other trade names may apply

Fruit Flies

- Treatments

  Cold: Dependent on fruit fly species. USDA APHIS approved treatments are available in some cases but can cause fruit damage.

  Fumigation: Methyl Bromide (MB) – APHIS approved but causes fruit damage.

  Heat: Approved but extremely phytotoxic.

  Irradiation: Expensive, sterilizes rather than disinfests; may not be acceptable to some trading partners.

Fruit fly research needs

- Better monitoring traps.
- Molecular techniques for determining species and origin for many species other than Medfly.
- Effective soil treatments.
- Sterile insect release methods for many species.
- Bait stations or attract and kill methods for applicable species.
- Eradication treatments.
- Impact of irradiation on fruit quality.
- Alternative quarantine treatments.
- Cultural or chemical management in the field to delay host susceptibility to quarantine pests.

Asian Citrus Psyllid

- Cultural controls: None available.
- Biological controls: A combination of native predators and introduced parasitoids is helping to control ACP in Florida and research is underway to find appropriate parasitoid species for California. At this point, ACP is under eradication with pesticides and so biological control programs have not been initiated in California.
- Chemical controls:

  Pyrethroids, organophosphates and carbamates are very effective against adult psyllids. but generally last only 4-6 weeks. These groups of insecticides are very toxic to natural enemies.

  Selective insecticide controls, that allow natural enemies to survive, include Delegate* and Movento*.

  Admire Pro* and generic imidacloprid (Couraze*, Alias*, Macho*) for nymphs is generally 85% effective, however Admire* is disruptive to natural enemies. There are also label restrictions associated with the use of Admire* during bloom due to bee toxicity. Also there are limits on the amount Imidacloprid* /acre per year. Foliar treatment with Imidacloprid* may take place in March or in the fall. The foliar treatment is even more disruptive to natural enemies than the systemic treatment.

  Organic treatments revolve around neem oil, petroleum oil and pyganic*, none of which provide protection for more than 2 weeks.

  There exist (in some areas) quarantine restrictions that prohibit the movement of uncleaned fruit, after harvest, to non-infested areas.

*Other trade names may apply.

ACP Research needs:

- Find additional insecticide chemistries for ACP area-wide treatment programs to improve IPM, human safety, and avoid selecting for resistance.
- Need a better understanding of the impact of the ACP areawide programs on natural enemies.
- Effective treatments for organic citrus – organic groves serve as a reservoir for ACP.
- Need postharvest treatments to disinfest fruit.
- Initiate research efforts on biological control of ACP for the California climate.

<u>Exotic Pest Needs:</u>

Potential exotics: brown citrus aphid and citrus tristeza virus, Caribbean root weevils, leprosis disease transmitted by flat mites, CVC transmitted by sharpshooters, lepidopterans, armored scales from Mexico, and many more that we can not anticipate.

- Better detection methods such as molecular techniques for strain and species differentiation.
- Research on resistant plant material for diseases.
- Basic biology and chemical control tactics.

Important Regulatory Needs

- There is a need for Codex and for all foreign markets MRLs for many insecticides (examples include: Danitol*; Delegate*; new miticides; Movento*).
- Allow orchard floor uses of ant controls as an incentive for broader registrations (in an attempt to obtain exemption from tolerance).
- Export Quarantine issues: Presence of these pests will limit movement of fruit to export countries: LBAM, citrus peelminer, GWSS issues for harvest and movement and protection from invasive pests.
- Regulators need to understand that strains of a particular species can vary greatly with respect to their pest status (virulence), host breadth, resistance to pesticides, etc. We need to learn from the example of the Mexican strain of citrus peelminer entering CA and becoming a major economic pest – citrus peelminer was not excluded because a relatively minor and non-pestiferous strain of this species was already present. The two strains are easily differentiated using molecular methods and the presence of extremely high levels on fruit should have been diagnostic to inspectors.

*Other trade names may apply

- More eyes on the borders to prevent invasive pests from entering California – internal and external. Preventing/monitoring species and strains of pests being imported into CA. Elevate the level of inspections of Ag products at borders and ports of entry. Re-instate the Beagle program.
- Internal quarantine issues: Leafminer Diaprepes, citrus peelminer, GWSS. Fire ant movement around the state needs to be limited to prevent infestations in new areas of the state. Evaluate the ratings of pests and the impact of movement of fruit and plant material through uninfested areas.
- Anticipated quarantine issues: Asian Citrus Psyllid, Brown Citrus Aphid, LBAM, many species of Fruit Flies, including but not limited to Mexican, Oriental and Mediterranean. Examine availability of eradication pesticide treatments for these pests. Watch for new species or strains moving in from other crops or countries (armored scales, worms).
- There is a need for more realistic label restrictions relating to bees. See "bee language" on the Success*, Delegate*, and Agri-Mek* labels.
- There is a need for registration of ant bait stations and pesticides that might be used in them. Fipronil* as toxicant in an ant bait station. ("The registrant MFG will not support" – see USDA IR-4 website).
- Obtain Section 18 for Micromite* for grasshopper and citrus leafminer for citrus varieties not already on the label.
- REIs need to be equal to, or shorter than, PHIs.
- Development of pest-free zones for export shipments.
- Evaluate VOC potential of new and existing chemicals and provide the information to the public.
- Evaluate impact of surface and ground water restrictions.
- Positioning of new insecticides and miticides into bearing crops due to resistance concerns limits their use in nonbearing citrus, greatly restricting the ability of nonbearing areas to rotate chemical classes and delay resistance.
- Sprayers – development of better equipment, effective, efficient.
- Need Gourmet* (boric acid) ant bait registered for non-organic uses.
- Need a broad citrus registration for Micromite* and Kanemite* (all citrus, not just certain varieties).
- Need registration of ethyl formate for bean thrips fumigation.
- Continued improvement of the pre-clearance rules (8 point work plan for bean thrips).
- Better survey of export areas before they ship to the U.S. – not just citrus crops.
- Peer review journals should NOT be the only input for development of risk assessments and in-progress research should be evaluated/allowed/included. (In some countries, surveys have not been done; the fact that no pests are reported doesn't mean they aren't there).

Important Educational Needs

- Continue existing educational programs, including mobile labs, brochures, web sites and grower seminars on existing and new pests.
- Educate regulatory community. Recent EPA/CDPR citrus tour, as an example.
- Educate citrus industry regarding new insecticides and their proper use and compatibility with existing Integrated Pest Management Programs.
- Education of registrants as to the need for ant bait stations. Need for more cost-effective bait stations.

*Other trade names may apply.

- Educate growers regarding managing pesticide resistance, in general, and withholding unnecessary treatments.
- Pesticide resistance issues: New products such as Success*/Delegate*, Admire*, and Esteem* are heavily relied upon for citrus thrips, GWSS, and red scale, respectively. This will eventually lead to resistance. Growers need to be taught to rotate chemistries and use nonchemical methods to reduce the rate of resistance development. In particular, Admire* & Esteem*/tank mixing/GWSS treatments.
- Overuse of insecticides when they are not needed because the pests are below an economic threshold.
- Late season applications of pesticides for citrus red scale are not very effective because you have multiple stages and overlapping generations.
- Educating growers about management of newly arrived pests: citrus leafminer, ACP, Diaprepes root weevil, LBAM.
- Differentiating LBAM from other worms.
- Importance of eradication and quarantine – educating the urban population – how exotic pests affect the food supply, etc.
- Packing house education – won't allow damaged fruit (Citrus bud mite or Silver Mite) even though research has shown yield does not increase with treatment.
- IPM systems education – sustainable (especially with regard to informing California DPR).
- Fragility of IPM systems as exotic pests are introduced and eradication programs utilize pesticides or the pest is not controlled at all.
- Spray application equipment and methods to improve efficiency and delay resistance and minimize pollution impacts.
- Proper use of equipment and methods, how to monitor coverage, etc.
- Proper timing and effective application of insecticides for citricola scale and citrus red scale, especially as the new systemic foliar insecticide Movento* is registered.
- Education on proper use of snail baits.

*Other trade names may apply

NURSERY CITRUS

I. Activities Occurring During this Time Period

- Planting seed
- Budding
- Fertilizing
- Irrigation
- Scouting
- Snail control
- Weed Control
- Vertebrate control
- Insect Control
- Mite Control
- Treatments prior to shipping due to quarantine restrictions (GWSS, CRS, ants) treatments in some areas

General Nursery Comments:

1. The Nursery Certification Program demands a zero or near zero tolerance for infestation (presence) of pests. Pests for which there is zero tolerance include California red scale, bud mite, purple scale, yellow scale, and GWSS. In addition, B rated pests ,such as citrus leafminer, must be prevented from moving into uninfested counties. The consequence of this is that cultural and biological control methods are often not sufficient to prevent infestations and nurserymen rely heavily on pesticides to eliminate pests.
2. Diseases such as Huanglongbing vectored by Asian citrus psyllid threaten the California nursery industry and will provide a strong motivation for the nursery industry to move into greenhouses and screenhouses during the coming years. This will protect the plants from larger pests such as psyllids and aphids, but increase the pressure from other pests such as mites and scales that do well in that environment and are difficult to exclude using screens.
3. Citrus nurserymen use diverse growing environments including greenhouses, screenhouses, outdoor plantings in pots and outdoor plantings in the ground. These situations promote different pests requiring different treatment tactics. Some of these differences in pest populations are noted below.

General Nursery Research Needs:

1. Coverage: pesticide coverage of dense plantings of trees is difficult – new technologies are needed.
2. Sanitation: the role of sanitation in pest prevention.
3. Admire* application methodology (sprinkler versus drip) to maximize effect.
4. Better screens for exclusion of pests from screenhouses and greenhouses as more and more nursery stock is placed under screen.
5. Use of oils for pest control. Frequent oil treatments are difficult in situations with wind, hot conditions or in urban situations. Registered budwood cannot be treated with oil.
6. IPM program for a screenhouse oriented industry – the future is an enclosed environment.
7. Evaluating the benefits and detriments of growing in a screenhouse (growth effects).

*Other trade names may apply

PEST(S) THAT NEED TO BE CONTROLLED IN THE NURSERY

California red scale

Chemical Control: Organophosphates (OPs), carbamates, Esteem*, Knack*, Admire*, oil
California red scale nursery research needs:

- Similar to field production needs (future of screenhouses, biological control may be feasible), more insecticides that are effective.

Brown soft scale

Chemical control: Provado*, Admire*, Assail*, malathion*, Lorsban*, Sevin*, – relatively easy to control.
Brown soft scale nursery research needs:

- Pesticide Resistance monitoring (currently use OPs, carbamates, and neonicotinoids).
- New chemistries for rotation to avoid resistance.

Mealybugs

Chemical Control: Flagship*, Admire*, carbamates, OPs - control is difficult.
Greenhouse (GH) Control Tactics: mealybug can exhibit heavy densities in the GH.
Outdoor control tactics: generally not a problem except on the coast.
Mealybug nursery research needs:

- Evaluate Applaud* and other new chemistries (Movento*) for greenhouse situations.
- Efficacy of releases of *Cryptolaemus* beetles.
- Test mealybug pheromones for better monitoring of populations.
- Sanitation/exclusion research to minimize infestations.

Citrus Leafminer

GH Control Tactics similar to outdoor tactics: Insecticides including: Assail*, Conserve*, Admire*, Oil, Ultiflora*, Micromite*, Provado*, Intrepid*.
Citrus leafminer nursery research needs:

- More effective insecticides: No insecticide kills every leafminer which makes it difficult for nurserymen to transport plant material to other counties.
- Frequent oil treatments (highly refined oils applied every 10-14 days at $\leq$ 0.25%).
- Pheromone disruption and trap/kill, especially in the greenhouse.
- Investigate mechanical control, a blacklight or other trap to attract moths and kill them with a water spray.
- Pesticide resistance monitoring.

Citrus thrips: significant in the desert and SJV

GH Control Tactics: minor problem, rarely treated in the greenhouse.
Outdoor control tactics: Conserve*, Veratran*.
Citrus thrips nursery research needs:

- More insecticide chemistries for effectiveness and resistance management.
- Overhead irrigation to reduce populations.
- IPM techniques: High humidity in GH + *Beauveria* + nematodes – test to see if effective.

*Other trade names may apply

Miscellaneous Lepidopteran pest: Bt, permethrin tank mix with Bt,

GH Control Tactics: *Bacillus thuringiensis* (Bt)* + permethrin* (or other synthetic pyrethroid, Tame* or Danitol*).

Outdoor control tactics: Kryocide*, Tame*.

Lepidopteran nursery research needs:

- Resistance to Bt should be studied.
- Screen new chemistries as they become available, especially materials specific to Lepidoptera.

Citrus bud mite

Chemical Control: No chemical control available for nurseries due to the long re-entry period for Lorsban* (4 day REI) + oil.

GH control tactics: bud mite is not a problem.

Outdoor control tactics: Need new insecticide chemistries.

Citrus bud mite nursery research needs:

- More insecticide screening for bud mite control: new miticides such as Envidor*, Micromite*, Judo*.
- Frequent oil treatments (0.25%) may be effective.

Citrus red mite, , Texas citrus mite, Yuma spider mite

Chemical Control: new miticides work well, Ultiflora* (nonbearing = NB) tank mixed with an ovicide (Hexygon* and Zeal*/Tetrasan* (NB) works for months, Kanemite* (certain varieties), Acramite (NB)*, Judo (NB)*, Tame*, Envidor*. Fewer outbreaks since OP and carbamates were reduced.

Spider mite nursery research needs:

- Frequent oil treatments at low rates may be effective.
- Pesticide Resistance monitoring.

Whiteflies

GH Control Tactics: neonicotinoids (Provado*, Assail*), Judo*, Botaniguard* (short lived).

Outdoor control tactics: not a problem.

Whitefly nursery research needs:

- New insecticide chemistries.

Aphids

Chemical controls: pyrethroids are variable in effectiveness (Danitol* and Tame* don't work well, but Talstar* does) and neonicotinoids work well.

Outdoor control tactics: Minor in SJV but on the coast aphids are a continuous problem.

Aphid nursery research needs:

- More insecticide chemistries to avoid resistance.
- Natural enemies: predatory beetles, syrphids, parasitoids.
- Interplants with flowers to attract syrphids.
- Pirimacarb* (carbamate) or other pesticides specific for aphids to be brought through the IR-4 program.
- Endeavor* insecticide appears to reduce feeding.

*Other trade names may apply.

Fungus gnats:

Biological Control: *Hypoaspis* predacious mite.
GH Control Tactics: sporadic, appear in potting media.
Outdoor control tactics: none.
Fungus gnat nursery research needs:

- Study predators and parasites of fungus gnats.
- Pathogens such as Gnatrol* (Bt).

Ants (red and black)

Chemical Control: Talstar*, Clinch*, Esteem* ant bait.
GH Control Tactics: rare.
Outdoor control tactics: more of a problem outdoor.
Ant nursery research needs:

- Better baits/toxicants for liquid sugar feeders.
- Better baits/toxicants for protein feeding ants.
- Methods for detecting ants in shipments of trees

Katydid

GH Control Tactics: not a problem (excluded).
Outdoor control tactics: serious problem in containers for retail sale. Chemical controls: pyrethroids, OPs, Kryocide*, Conserve*.
Katydid nursery research needs:

- Pesticides more specific for katydids.
- Traps and baits to collect/control them.

Earwigs: An emerging problem as pesticides with long-residual activity are no longer used.
Chemical control: Lorsban*, Sevin*.
Earwig nursery research needs:

- Effective products – better baits + toxicant (new reduced risk pesticides).
- Sanitation.
- Mechanical control: Collection in tubes/cardboard.

Snails/slugs

Chemical control: Deadline mini pellets, Metarex* pellets last the longest, Mesurol* to spray on the plant to knock out the small snails.
Snail/slug nursery research needs:

- Need to balance of using the smallest pellet possible (Protect animals) and to have longest persistence to minimize application frequency.
- Study Aquatic slugs in the irrigation system.

*****Other trade names may apply.

Potential Exotic pests:

Diaprepes root weevil
Asian citrus psyllid
Brown citrus aphid

Exotic pest nursery research needs:

- Monitoring methods.
- Chemical treatments.

II. Important Nursery Regulatory Needs

- The combination of re-entry intervals (REI) and worker protection (PPE) makes use of some of the pesticides difficult (Lorsban*, Supracide*, Omite*, Carzol*, Naled*, Kelthane*).
- Pesticides in the water are an issue
  - o Urban water run-off (irrigation, storm) – OPs, pyrethroids, bifenthrin*,
  - o Non-Target Aquatic Systems – Insect growth regulators affect crustaceans
- Nurseries don't have access to some products that are used in production citrus in order to reduce the rate of resistance development in key field pests such as citrus thrips – limiting the number of applications per season could be a compromise to allow registration in nurseries.
- Because of the nursery stock certification program there is "near-zero tolerance" for the presence of pests.
- Newly arrived pests: develop programs controlling movement between regions, counties and states.
- Consistency of enforcement for invasive pests - for example: zero-tolerance for B-rated pests such as citrus leafminer escalates pesticide treatments.
- Eliminate the restrictions on California red scale (and others) between CA and AZ (they have zero-tolerance – "no live pests") – need more realistic compliance agreements.
- Need to anticipate exotic pest introductions and pesticide registrations that will be needed in urban areas, nurseries and agriculture – for eradication programs.
- Section 18 preparation – need to be ready to move immediately, especially for the Asian citrus psyllid, as exotic pests appear (action plans are needed).

III. Important Nursery Education Needs

- Resistance management – nurserymen and workers.
- Pesticide runoff issues.
- Worker safety and public relations with neighbors – schools.
- Calibration of equipment and rates of chemicals, especially systemic Admire.*
- Sanitation.
- General education on new pests.
- Educating nurserymen on issues they will face as they move their production into greenhouse and screenhouses.

*Other trade names may apply.

CRITICAL NEEDS FOR NURSERY AND PRODUCTION CITRUS

(All items in lists of equal importance)

Critical Nursery Citrus Research Needs

- Coverage: pesticide coverage of dense plantings of trees is difficult – new technologies are needed.
- Sanitation: the role of sanitation in pest prevention.
- Admire application methodology (sprinkler versus drip) to maximize effect.
- Better screens for exclusion of pests from screen houses and greenhouses as more and more nursery stock is placed under screen.
- Use of oils for pest control. Frequent oil treatments are difficult in situations with wind, hot conditions or in urban situations. Registered budwood cannot be treated with oil.
- IPM program for a screen house oriented industry – the future is an enclosed environment.
- Evaluating the benefits and detriments of growing in a screen house (growth effects).
- More effective pesticides against common pests and exotic pests, since biological control is not feasible in the nursery situation or in eradication programs.
- Pesticide resistance management through registration of new insecticide classes and use rotation schemes.

Critical Nursery Citrus Regulatory Needs

- Long re-entry intervals (REIs) and the requirement of worker personal protective equipment (PPE) make some of the pesticides difficult to use (Lorsban*, Supracide*, Omite*, Carzol*, Naled*, Kelthane*).
- Pesticides in the water are an issue
    - Urban water run-off (irrigation, storm) – OPs, pyrethroids, bifenthrin*
    - Non-Target Aquatic Systems – Insect growth regulators affect crustaceans
- Nurseries don't have access to some products that are used in production citrus in order to reduce the rate of resistance development in key field pests such as citrus thrips – limiting the number of applications per season could be a compromise to allow registration in nurseries.
- Because of the nursery stock certification program there is "near-zero tolerance" for the presence of pests rendering biological control programs infeasible and escalating pesticide use.
- Newly arrived pests: develop programs controlling movement between regions, counties and states.
- Consistency of enforcement for invasive pests - for example: zero-tolerance for B-rated pests such as citrus leafminer escalates pesticide treatments.
- Eliminate the restrictions on California red scale (and others) between CA and AZ (they have zero-tolerance – "no live pests") – need more realistic compliance agreements.
- Need to anticipate exotic pest introductions and pesticide registrations that will be needed in urban areas, nurseries and agriculture – for eradication programs.
- Section 18 preparation – need to be ready to treat immediately with pesticides especially for the Asian citrus psyllid (Need action plans) as exotic pests appear.

*Other trade names may apply.

Critical Nursery Citrus Education Needs

- Resistance management – nurserymen and workers
- Pesticide runoff issues
- Worker safety and public relations with neighbors – schools
- Calibration of equipment and rates of chemicals, especially systemic Admire*
- Sanitation
- General education on new pests
- Educating nurserymen on issues they will face as they move their production into greenhouse and screen houses.

Critical Production Citrus Research Issues

- Research on effective use of insecticides for exotic pests such as LBAM, Diaprepes, fruit flies, and exotic pests not yet arrived such as Asian citrus psyllid, brown citrus aphid, and Caribbean weevils with considerations for IPM and resistance management.
- Effective replacement of VOC producing pesticides, researched and used in a public relations promotion to demonstrate to the public that agriculture is concerned with the environment.
- Better understanding of the negative impact of ants (especially Argentine ants) on parasites and predators of citrus pests and improved toxicants, bait formulations, baiting systems, and strategies for baiting for ant control.
- Long-term impacts of various types of chemical control on pest and natural enemy populations in the context of IPM and resistance management.
- Improved spray technology to more effectively control citrus pests while minimizing drift.
- Develop molecular markers for pests to identify strains and determine origins.
- Basic biology and integrated control of pests that emerge as a result of shifts in pesticide practices (e.g. katydids, citricola scale, earwigs).
- Basic biology and integrated control of pests as they become established in California (e.g. LBAM, Diaprepes root weevil, citrus leafminer, imported fire ant, glassy-winged sharpshooter).
- Determination of economic thresholds (effects on citrus yield and fruit quality) for pests such as citrus bud mite, citricola scale, cottony cushion scale, citrus leafminer that are currently lacking thresholds.
- Foreign exploration for natural enemies for invasive pests lacking adequate biological control.
- Fumigation, temperature, irradiation and other control methods for pests infesting fruit that are of export/import concern (e.g. bean thrips, fruit flies).

Critical Production Citrus Regulatory Issues

- Greater control of the border stations, airports, ships and other avenues of pest infested plant material and containers to prevent introduction of new species or strains of pests from entering California.

*Other trade names may apply.

- Anticipate insecticides needed for eradication of exotic pests (Asian citrus psyllid, brown citrus aphid, LBAM, fruit flies etc.) and develop registrations for agriculture, backyard and nursery situations for both ornamentals and food crops.
- There is a need for Codex and export country MRL's for insecticides (examples include Esteem*, Danitol*, Delegate*, Movento* and any new active ingredients as soon as they are registered in the U.S.)
- Internal quarantine issues: Leafminer, Diaprepes, Peelminer, GWSS, fire ant movement around the state needs to be limited to prevent infestations in new areas of the state. Evaluate the ratings of pests and the impact of movement of fruit and plant material through uninfested areas.
- There is a need for more realistic label restrictions relating to bees.
- There is a need for registration of ant bait stations and pesticides that might be used in them.
- REIs need to be equal to, or shorter than, PHIs.
- Development of pest-free zones for export shipments.
- Evaluate the VOC potential of new and existing pesticides.
- Evaluate impact of surface and ground water restrictions.
- Need a broad citrus registration for some insecticides, not just certain citrus varieties (Micromite* and Kanemite*).
- Need registration of products such as ethyl formate for fumigation of fruit to disinfest it of pests such as bean thrips and glassy-winged sharpshooter.
- Continued improvement of the pre-clearance rules for pests where available (e.g. Eight point work-plan for bean thrips).

Critical Production Citrus Education Issues

- Educate the chemical industry registrants as to the need for ant bait stations and formulations.
- Educate the citrus industry regarding new insecticides and their proper use and compatibility with existing IPM programs.
- Educate growers to rotate insecticides from different chemical classes to avoid selecting for resistance.
- Educate the public about the impact on their food supply when exotic pests are introduced and not eradicated.
- IPM systems education for growers and regulatory agencies.
- Educate growers about spray application equipment, methods to improve efficiency and minimize pollution impacts.
- Educate regulatory community about citrus production constraints.
- Educating growers about identification and management of newly arrived pests: citrus leafminer, Diaprepes root weevil, LBAM.
- Packing house education on fruit damage evaluation.
- Fragility of IPM systems as exotic pests are introduced and eradication programs utilize pesticides or if the pest is not controlled at all.
- Proper use of spray equipment and methods, how to monitor coverage, etc.

*****Other trade names may apply.

WEED CONTROL – BY SEASON

PRE-BLOOM (February - March)

1. Chemical Controls

- **Diuron*:** Ground water issues/surface water runoff issues.
- **Glufosinate*:** burndown material, with no residual activity.
- **Glyphosate*:** Important weed – malva - is difficult to control. In some areas of the Central Valley populations of glyphosate*- resistant horseweed and hairy or flax leaf fleabane have been documented. Glufosinate* is being used now for this reason, by some growers. (Glyphosate* costs have increased substantially recently.)
- **Krovar* (bromacil*/diuron*):** Ground water issues/surface water runoff issues.
- **Paraquat*:** Worker safety issues associated with its use.
- **Simazine*:** ground water/surface water issues. Use may be retained but use patterns will likely change.

2. Cultivation as a means of control

- **Burning/torching:** Not frequently used but is effective. Used by organic growers.
- **Disc middles:** There exists the potential to damage tree roots.
- **Mowing**

3. Important Research Needs

- Weeds may serve as host for glassy-winged sharpshooter (GWSS) nymphs to complete their life cycle in the second generation; however GWSS is being well managed with insecticides in citrus and grapes.
- Weeds serve as hosts for beet leafhoppers who transmit "stubborn" disease.
- Vegetation on the orchard floor during the frost season adds to the risk of frost damage; this vegetation may be in the form of weed species or a seeded cover crop. Dense stands of vegetation pose a greater risk of lowering nighttime temperatures. Where cover cropping is practiced, planting in late fall (November) reduces the risk because of minimal growth of the cover crop during the frost season.
- Emerging weed problems include flax leaf fleabane, horseweed, malva, and common groundsel, which are becoming more of a problem in the San Joaquin Valley.

4. Important Regulatory Needs

- Impact of regulations surrounding ground and surface water runoff. Great need for consistency between agencies at all levels, i.e. county, state, and federal.

5. Important Education Needs

- Herbicide resistance management training

*Other trade names may apply.

BLOOM (March - April)

1. Chemical Controls

- **Glyphosate:** Resistance in flax leaf fleabane and horseweed (Conyza spp.), malva continues to be difficult to control.
- **Trifluralin*:** Applied via chemigation, residual period is 2-12 months.
- **Solicam*:** Applied via chemigation, limited activity on some broadleaf weed species; may not be used on coarse-textured soils or south of Monterey, Kings, and Tulare counties.
- **Paraquat Dichloride*:** Best results when weeds are less than 4 inches tall, use requires closed system, post-emergence use only.
- **Surflan*:** Excellent control over many grasses and broadleaves. Used as a pre-emergent herbicide. Residual period; 4-10 months.
- **Devrinol*:** Light use in young plantings, residual period 4-10 months, poor control on several broadleaf weed species, documented to break down when used under drip irrigation systems.
- **Visor*:** Controls several annual grasses and broadleaf weeds and provides suppression on several difficult weed species. Expensive.

2. Cultivation as a means of control

- **Burning/torching:** used infrequently but is effective. Organic growers may use.
- **Disc middles:** caution must be used to avoid damage to tree roots.
- **Mowing**

3. Important Research Needs

- Need to develop new herbicides; there have been no new herbicides registered for some time.
- Need to find effective pre or post emergent herbicide or alternative methods to control malva.
- Bloom sprays for mandarins (thinning and fruit set sprays, PGRs).
- Need to test the efficacy of non-toxic bee repellents or inhibitors of pollen germination and pollen tube growth to reduce seediness of mandarins.

4. Important Regulatory Needs

- Need new products.

5. Important Education Needs

- New, onerous restrictions on chemigation and increasing regulatory scrutiny on all pesticides with high volatile organic compound (VOC) emissions.

*Other trade names may apply.

PETAL FALL (April thru May)

Generally in maintenance mode during this time of the year.

- Cultural: None at this time
- Biological: None at this time
- Chemical:
  - **Glyphosate*:** Flax leaf fleabane and horseweed are resistant in some areas, malva is difficult to control, no residual activity, post emergence use only
  - **Paraquat Dichloride*:** Best results when weeds are less than 4 inches tall, use requires closed system, post-emergence use only.

PRE-HARVEST THROUGH HARVEST (September – January)

A minority of growers plant winter/fall cover crops, which works well where frost is not a problem and erosion control is practiced. Weeds: In addition to existing weed problems, flax leaf fleabane, horseweed and common groundsel are becoming more of a problem in the San Joaquin Valley.

1. Chemical Controls

- **Simazine*:** Weak on many grasses. Product may not be used on sandy or gravelly soils where product may move into the root zone and damage roots. Groundwater problems associated with the use of this product. Found on California's Groundwater Protection "A" List.
- **Diuron:** Phytotoxicity when used on sand, loamy sand or gravelly soils. On California's Groundwater Protection "A" List.
- **Glyphosate:** No residual activity. Post emergence use only. Must avoid drift.
- **Paraquat Dichloride:** Best results when weeds are less than 4 inches tall, use requires closed system, post-emergence use only. Also worker safety issues concerning use of this product.
- **Krovar *(bromacil/diuron):** On California's Groundwater Protection "A" List. Can be phytotoxic when used on soils with less than 1% organic matter.

2. Cultivation as a means of control

- **Burning/torching:** (not frequently used but is effective/maybe organic). Possible regulatory issues with particulate and smoke.
- **Disc middles:** (potential damage to tree roots)
- **Mowing:** Possible regulatory issues with particulate and smoke.

3. Important Research Needs

- Weeds may serve as host for glassy-winged sharpshooter (GWSS) nymphs to complete life cycle in the second generation.
- Weeds serve as hosts for beet leafhoppers who transmit "stubborn" disease.

*Other trade names may apply.

- Vegetation on the orchard floor during the frost season adds to the risk of frost damage; this vegetation may be in the form of weed species or a seeded cover crop. Dense stands of vegetation pose a greater risk of lowering nighttime temperatures. Where cover cropping is practiced, planting in late fall (November) reduces the risk because of minimal growth of the cover during the frost season.
- More research on cover crops (need to identify species and mixtures of species and consequences of their use). Study should include an economic analysis of the cost of potential additional water and nutrient needs and impacts on frost hazard.
- Research newer herbicides which are generally used at lower rates.
- Weed resistance. Which species to what chemicals?
- Cost benefit of weed control.
- New application technologies in citrus.
- Use of mulches as a weed suppressant (possible insect control as side benefit).

4. Important Regulatory Needs

- Impact of regulations surrounding ground and surface water runoff. Great need for consistency between agencies at all levels, i.e. county, state, and federal.
- Register additional (newer) herbicides.

5. Important Educational Needs

- Educate on mitigation of groundwater and other off-target effects of herbicides
- New application technologies.
- Use of mulches as a weed suppressant (possible insect control as side benefit).
- Important to educate growers on not letting weeds set seeds.

PREHARVEST USES OF PLANT GROWTH REGULATORS FOR CITRUS IN CALIFORNIA

The UC IPM Pest Management Guide: Citrus, Plant Growth Regulators

This section provides an overview of current uses of PGRs in citriculture in California. The reported information is subject to change. Thus, it is imperative that you check the website of the University of California Integrated Pest Management Guide for Citrus for current registered uses, label rates, proper application time and approved citrus crops before implementing your management strategy and applying treatments. In addition, the website includes numerous cautions, of which you need to be aware when using PGRs to manage your crop, and guidelines for ensuring and enhancing the efficacy of your PGR treatments. The information provided is intended to guide you in the use of commercial PGRs for solving specific production problems.

At the time of writing, 2,4-dichlorophenoxyacetic acid (2,4-D*), gibberellic acid (GA_{3*}), and naphthaleneacetic acid (NAA*) are registered for preharvest use on California citrus crops. Use of 2,4-D *is mainly to delay and reduce unwanted fruit abscission (fruit drop) of 'Navels', 'Valencias', lemons, grapefruit, and tangelos and other mandarin hybrids; GA_{3*} is used mainly to delay senescence (over ripening) of 'Navels', 'Valencias', tangerines (mandarin) hybrids, lemons and limes; and NAA is used to promote abscission of excess fruit (thinning to increase the size of the remaining fruit) of orange varieties, tangerines (mandarins), tangelos and tangors, and to inhibit the growth of suckers on the trunk of nonbearing citrus trees. GA_{3*} is also registered for use to increase fruit set of Clementine mandarins, and 2,4-D, is registered to increase fruit size of 'Navels', 'Valencias', grapefruit, mandarins and mandarin hybrids, and to prevent leaf and fruit drop after an oil spray. For application times and rates to be used for each PGR for a given purpose, please refer to the University of California Integrated Pest Management Guide for Citrus.

To reach the UC IPM Pest Management Guide for Citrus PGRs, go to http://www.ipm.ucdavis.edu/PMG/ and follow the links. Be sure to access the link to "General Information" to review the necessary cautions. Each site also has a link to "Precautions," which provides a general set of guidelines for using pesticides, which includes plant growth regulators.

*Other trade names may apply.

PRIORITY CRITICAL NEEDS

Priority Research Needs (random order)

- Overall objective to develop an economical and effective integrated program that maximizes biological control and minimizes non-selective insecticides.

- Need better understanding of the impact of the GWSS suppression program on natural enemies. Research winter/fall treatments for GWSS vs. Spring treatments (which is the least disruptive?). Search for GWSS treatments that are compatible w/ IPM.

- Develop economical and practical ant control systems that work on sugar-feeding ants (Argentine and native gray ants) in order to improve biological control of various pests. Problems associated with bait stations: economics, regulatory issues.

- Continue research efforts on biological control of newly introduced pests such as GWSS, citrus peelminer and citrus leafminer (not yet in SJ Valley that we know of but is predicted) as well as established pests such as citricola scale.

- Continued research on monitoring and methods to reduce levels of bean thrips and other phytosanitary pests (e.g. citrus peelminer, GWSS, fruit flies) in export shipments, postharvest controls.

- Pesticide Resistance issues: red scale (Esteem*), GWSS (Admire*), and citrus thrips (Success*). New insecticides for citrus thrips and red scale will be needed.

- Develop alternative quarantine treatments.

- Continue research on pre-bloom, bloom, petal fall and/or June drop foliar applications of PGRs [2,4-dichlorophenoxyacetic acid (2,4-D*), 2,4,-dichlorophenoxyproprionic acid (2,4-DP*), 3,5,6-trichloro-2-pyridyloxyacetic acid (3,5,6-TPA*), gibberellic acid (GA3*), 6-benzoyladenine (BA*), N-(2-cloro-4-pyridinyl)-N-phenylurea (CPPU*), aminoethoxy- vinylglycine (AVG)*] for improving fruit set and size of mandarins, maximum peel thickness foliar PGR applications for increasing fruit size [2,4-DP*), 3,5,6-trichloro-2pyridyloxyacetic acid (3,5,6-TPA*), gibberellic acid (GA3*), 6-benzoyladenine (BA*), N-2-cloro-4-pyridinyl)-N-phenylurea (CPPU*)] to increase fruit size, and Pre-harvest foliar applications to prevent Pre-harvest fruit drop and improve fruit quality of late harvested fruit [gibberellic acid (GA3*), 6-benzoyladenine (BA*), N-(2-cloro-4-pyridinyl)-N-phenylurea (CPPU*), aminoethoxyvinylglycine (AVG*)].

- Need to test the efficacy of non-toxic bee repellents or inhibitors of pollen germination and pollen tube growth to reduce seediness of mandarins.

*Other trade names may apply.

- Pre-plant fumigants for those citrus replants where pre-plant fumigation is really needed. Current products of interest include methyl iodide and sodium azide

- Field evaluation of new post-plant nematicides.

- Post-plant nematicide rotation procedures that ensure continued performance of new products that are under study (avoid increased product degradation over time).

Priority Regulatory Needs – random order

- Codex and or export market country MRLs for insecticides including Esteem, Danitol*, Movento* and Delegate*. Expedite US registration of Platinum* for GWSS.

- Quarantine issues: GWSS issues for harvest and movement.

- Need registration of ant bait stations.

- Registration of alternative products for resistance management of citrus thrips, California red scale, silver/citrus rust mite.

- Regulations governing movement of exotic pests need to be strengthened.

Priority Educational Needs – random order

- Educate state and federal regulatory community. Need a follow up to the March 2008 EPA/CDPR tour. Real need for season-long understanding of how management methods fit into IPM

- Educate local regulators with respect to proper timing of GWSS treatments.

- Understanding of impact of invasive pests

- Educate citrus industry re Citrus IPM: new insecticides/proper use & compatibility with IPM. pH education for Success* and Veratran*. Need to keep Success* above 6 pH and acidify Veratran* to 4.5 pH. Need to not treat flower thrips population, easily confused with citrus thrips. Education re: managing pesticide resistance, in general, and withholding unnecessary treatments. Unlikely to have new insecticides registered. Scarring related to pest damage. Late season applications of pesticides for California red scale are not very effective because you have multiple stages and overlapping generations.

*Other trade names may apply.

Critical Needs - Other

Research Needs (random order)

- Citrus bud mite is the number one problem in the coast region. There is the need for a non-oil dependent control, which is compatible with biological controls.
- Need to investigate Evergreen*, ethyl formate, methyl salicylate and temperature on bean thrips survival.
- Cutworm indigenous biological control.
- Continue research to establish thresholds for treatment requirements. Threshold for GWSS is zero in the eyes of the grape growers.
- Need to better understand endemic biological control of katydids and what materials cause disruption.
- Need to find effective, pre or post emergent herbicide on malva.
- Economic thresholds for citrus thrips with new and/or selective materials.
- Need for new insecticides for citrus thrips.
- Need research on control measures for earwigs and/or other sporadic pests that emerge, i.e. grasshoppers, etc.
- More research on selective citricola scale treatments. Need treatment with biological controls.
- More research into rootstocks which are truly resistant to aggressive biotypes of citrus nematodes.
- Coordinated effort to rotate citrus ground to avoid aggressive biotypes of citrus nematodes.

Regulatory Needs (random order)

- Applaud* 60 day PHI is problem. Cannot be used for Valencias. Good IPM tool, need shorter PHI so it can be more effectively used.
- Impact of ground and surface water runoff. Need consistency between agencies (counties, state, Fed).

*Other trade names may apply.

- Realistic label restrictions relating to bees (see Success*/Agri-Mek* labels).
- Obtain Section 18 for Micromite* for grasshopper and citrus leafminer.
- REIs need to be equal to, or shorter than, PHIs.

Educational Needs – random order

- Continue existing educational programs. Includes mobile labs, book on GWSS (update), grower seminars.
- Need weed identification/Citrus IPM Manual needs to be completed.
- Education of registrants as to the need for ant bait stations.
- Chemigation: examine new restrictions associated with chemigation.
- Timing of glyphosate use.

*Other trade names may apply

Effects of International Issues

- The MRLs in export markets are rarely the same as U.S. standards. A very comprehensive data base of US, Codex, European Union and more than 50 export market MRLs is now available at mrldatabase.com. The data base is updated daily and is funded by USDA-FAS and EPA.

- There is a need for Codex and National MRL's for insecticides for all foreign markets (examples include Danitol*, Delegate*, Movento*) and future new active ingredients as soon as they are registered in the US.

- Many pest and disease concerns and restrictions in export markets are used as trade barriers to prevent the exporting of citrus from the United States. Some of the quarantine pests identified by export market countries require pesticide treatments that are not warranted for the production of the crop in the United States.

- Imported produce can be the source of pest and disease outbreaks that require intense pesticide use and possible quarantine protocol treatments that disrupt IPM and the marketing of fruit.

*Other trade names may apply.

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ACRONYMS

APHIS –	USDA Animal Plant Health and Inspection Service
CARS –	CA red scale
CCQC –	CA Citrus Quality Council
CCS –	cottony cushion scale
CITS –	citricola scale
PGR –	plant growth regulator
CLM –	citrus leafminer
CRS –	citrus red scale
CUE –	critical use exemption
CVC -	citrus variegated chlorosis
DPR –	Department of Pesticide Regulation
EC –	Emulsified Concentrates
EPA –	Environmental Protection Agency
GH -	greenhouse
GWSS –	glassy winged sharp-shooter
HLB –	huanglongbing
IPM –	integrated pest management
IR4 –	USDA Interregional Project Four
LBAM –	light brown apple moth
MEP –	minimal exposure pesticide
MRL –	maximum residue limit
OP -	organophosphate
PAA –	peroxyacetic acid
PHI –	pre-harvest interval
PMSP –	pest management strategic plan
REI –	re-entry interval
SJV –	San Joaquin Valley
SOPP –	sodium o-phenylphenol
Spp –	species
TBZ –	thiabendazole
UC –	University of California
VOC –	volatile organic compound

Overview of sanitation treatments used in citrus fruit industries

Sanitation treatments prevent the spread of human and plant disease-causing micro-organisms (i.e. by water or equipment contact) that contaminate fruit, but unlike fungicides, they do not control fruit infections in wounds that occurred at harvest and during handling nor do they prevent future infections (i.e., no residual activity). They also help to prevent fungicide resistance by reducing airborne and fruit and equipment surface inoculum levels (e.g., propagules) of disease organisms. At the proper concentration and conditions, each of the sanitizers listed below can be effective, but each has advantages and disadvantages. Several of the treatments are used in an integrated fashion to improve the overall effectiveness and to prevent over-usage of any one treatment.

Sanitation treatments for fruit, equipment, and fruit processing facilities

Sodium hypochlorite (liquid) -
This compound is broad spectrum, economical, and relatively easy to measure (indirectly by ORP, or directly using test kits or test strips). Use requires pH control and effectiveness is strongly affected by water quality and organic matter. The compound is corrosive to carbon steel, and to a lesser degree to galvanized steel, and aluminum, whereas stainless steel may pit. Sodium hypochlorite has a chlorine odor from non-toxic chloramines that form when the compound reacts with organic material. Chloramines may be irritants to workers. Other reactive products (e.g., sodium) may be a disposal problem in some municipalities.

Calcium hypochlorite (solid) -
Similar to sodium hypochlorite, but more shelf stable as a solid. The formulation requires a flow-through delivery system to control concentration. Calcium hypochlorite is a good option where sodium discharge is an issue.

Chlorine dioxide -
Active across a wide pH range (does not require pH control). Chlorine dioxide requires on-site generation equipment

Peracetic acid (syn. - peroxyacetic acid, or acidified hydrogen peroxide) (liquid) -
Active across a wide pH range but requires some pH control for optimal performance. More stable at higher temperatures and in dirty or poor quality (i.e. hard) water than chlorines. No rinse required when used up to 80 ppm and it has a good discharge profile. Corrosion properties are similar to sodium hypochlorite, but will not pit stainless steel. The compound can be measured with test strips or test kits. Peracetic acid has a vinegary odor and may be an irritant at stock concentrations to handlers and mixers. If mixed with cleaning solutions, volatile acetic acid may be liberated. Worker safety and training is required.

Ozone -
This compound can be used in water or as a gas in air. In air, levels required for effective surface sanitation can be injurious to fruit. However, safe levels can be effective to slow sporulation of stored fruit and destroy atmospheric ethylene. In water, no rinse is required and it has good discharge profile, but it also requires clean water and sand-filtration systems. Difficulty in measuring and maintaining concentration in dirty or poor quality water make its use impractical under most commercial conditions. In water or air, requires on-site generation equipment and air monitoring to stay below OSHA exposure levels. Safe levels can be irritating to some workers. Ozone is corrosive to iron and mild steel and damages some rubbers and plastics.

Sanitation treatments for equipment and fruit processing facilities –(not to be used directly on fruit)

Quaternary ammonium compounds -
Salts of these materials may be used for disinfecting food handling equipment. They are odorless, have low corrosive properties, are active across a wide pH range, and are stable at high temperatures. These compounds are effective against molds, but ineffective against some bacteria such as *E. coli* at common use rates. Use rates higher than 200 ppm require a fresh water rinse on fruit contact surfaces (equipment/bins) to avoid leaving a residue high enough to burn fruit and to prevent damage to surfaces of older plastic bins.

Formaldehyde -
This compound is very effective as a fog treatment for disinfecting storage rooms and equipment in the absence of fruit. The application of formaldehyde in a facility is limited to two times per year. Buffer zones and worker re-entry restrictions may be prohibitive for widespread use.

www.ipm.ucdavis.edu

Citrus Year-Round IPM Program
Annual Checklist

Supplement to UC IPM Pest Management Guidelines: Citrus

These practices are recommended for a monitoring-based IPM program that reduces water and air quality problems related to pesticide use. Track your progress through the year using this form.

Water quality becomes impaired when pesticides move off-site and into water. Air quality becomes impaired when volatile organic compounds move into the atmosphere. Each time a pesticide application is considered, review the Pesticide Application Checklist at the bottom of this form for information on how to minimize air and water quality problems. This year-round IPM program covers major pests of citrus grown in California's Central Valley. Details on carrying out each practice, information on additional pests, and additional copies of this form are available from the UC IPM Pest Management Guidelines: Citrus at http://www.ipm.ucdavis.edu/PMG.

✓ Done	**Prebloom activities (January through March)** **Special issues of concern related to water quality:** Drift and runoff.
	Monitor California red scale males using pheromone-baited sticky traps (March through October), plus additional methods depending on the situation. ▪ Keep records of scale monitoring results. ▪ Learn to distinguish male scales from scale parasites and other important insects caught in sticky traps. ▪ Release *Aphytis melinus* if biological control is compatible with the overall management program.
	Look for spider mites and other mites. ▪ Monitor leaves for citrus red mite (February through June). ▪ Keep records of mite monitoring results. ▪ Look for natural enemies, especially *Euseius tularensis*. Manage if needed according to PMG.
	Look for cottony cushion scale and predatory vedalia beetles (March through July). ▪ Collect and relocate vedalia to cottony cushion scale-infested orchards if vedalia have not arrived by the end of March.
	Look for other pests and their damage to fruit or damage to leaves and twigs, especially: ▪ Earwigs (March through June) ▪ Forktailed bush katydid (March through June) ▪ Caterpillars, including amorbia, citrus cutworm, fruittree leafroller, omnivorous leafroller and orange tortrix Manage if needed according to PMG.
	Look for brown garden snail. ▪ Collect and relocate predatory decollate snails if decollates were not previously found in the orchard, brown garden snail has been a problem, and decollate introductions are permitted in your county. Manage if needed according to PMG.

✓ Done	Prebloom activities (continued)
	Look for diseases that cause symptoms on fruit, leaves and twigs, and on limbs, trunks, and roots, especially: ▪ Bacterial blast (Citrus blast) ▪ Brown rot and Septoria spot fruit decays ▪ Dry rot ▪ Phytophthora gummosis and Phytophthora root rots Record the date and location of problem trees or sites. Manage if needed according to PMG.
	Survey winter weeds. Identify common winter broadleaves and grasses. ▪ Record weed survey results at least twice annually (during late winter and in summer). Manage vegetation if needed according to PMG.
	Look for vertebrates, especially ground squirrels, pocket gophers, rabbits, and roof rats. Manage if needed.
	Provide proper cultural care and good growing conditions to improve tree health and fruit yield, including: ▪ Fertilize if needed. ▪ Inspect irrigation systems by late winter and irrigate if rainfall has been insufficient. ▪ Provide frost protection when cold threatens. ▪ Prune if needed, but only after frost is no longer a threat.
	Harvest mature fruit in coordination with other management activities to ensure good postharvest fruit quality and food safety. ▪ Educate and supervise workers regarding fruit-handling Best Management Practices (BMPs) ▪ Inspect fruit quality before bins are moved from the picking site to identify grove areas where management practices need improvement.

✓ Done	Bloom activities (April) **Special issues of concern related to water quality:** Drift, runoff, and volatile organic compounds (VOCs).
	Monitor California red scale males using pheromone-baited sticky traps (March through October), plus additional methods depending on the situation. ▪ Keep records of scale monitoring results. ▪ Distinguish male scales from scale parasites and other important insects caught in sticky traps. ▪ Release *Aphytis melinus* if biological control is compatible with the overall management program.
	Look for spider mites and other mites. ▪ Monitor leaves for citrus red mite (February through June). ▪ Keep records of mite monitoring results. ▪ Look for natural enemies, especially *Euseius tularensis* and sixspotted thrips. Manage if needed according to PMG.

✓ Done	Bloom activities (continued)
	Look for cottony cushion scale and predatory vedalia beetles. ▪ Collect and relocate vedalia to cottony cushion scale-infested orchards if vedalia have not arrived on their own during April.
	Look for other pests and their damage to fruit or damage to leaves and twigs, especially: ▪ Earwigs (March through June) ▪ Forktailed bush katydid (March through June) ▪ Caterpillars, including amorbia, citrus cutworm, fruittree leafroller, omnivorous leafroller, and orange tortrix Other pests: ▪ Ants, including fire ants and gray ants ▪ Citricola scale honeydew and females on twigs (be sure to distinguish citricola scale from brown soft scale) Manage if needed according to PMG.
	Look for brown garden snail. ▪ Collect and relocate predatory decollate snails if decollates were not previously found in the orchard, brown garden snail has been a problem, and decollate introductions are permitted in your county. Manage if needed according to PMG.
	Manage pesticides to avoid killing honey bees.
	Look for diseases that cause symptoms on fruit, leaves and twigs, and on limbs, trunks, and roots, especially: ▪ Brown rot and Septoria spot fruit decays ▪ Dry rot ▪ Phytophthora gummosis and Phytophthora root rots Record the date and location of problem trees or sites. Manage if needed according to PMG.
	Provide proper cultural care and good growing conditions to improve tree health and fruit yield, including: ▪ Fertilize if needed. ▪ Irrigate and adjust scheduling to meet trees' varying water needs. ▪ Prune if needed.
	Harvest mature fruit in coordination with other management activities to ensure good postharvest fruit quality and food safety. ▪ Educate and supervise workers regarding fruit-handling Best Management Practices (BMPs) ▪ Inspect fruit quality before bins are moved from the picking site to identify grove areas where management practices need improvement.

✓ Done	**Petal fall activities (late April through May)** **Special issues of concern related to water quality:** Drift, runoff, volatile organic compounds (VOCs).
	Monitor fruit for immature citrus thrips (late April through June). ▪ Keep records of thrips monitoring results. ▪ Examine leaves for natural enemies, such as *Euseius tularensis*. Manage if needed according to PMG.
	Monitor California red scale males using pheromone-baited sticky traps (March through October), plus additional methods depending on the situation. ▪ Keep records of scale monitoring results. ▪ Distinguish male scales from scale parasites and other important insects caught in sticky traps. ▪ Release *Aphytis melinus* if biological control is compatible with the overall management program.
	Look for spider mites and other mites. ▪ Monitor leaves for citrus red mite. ▪ Keep records of mite monitoring results. ▪ Look for natural enemies, especially *Euseius tularensis* and sixspotted thrips. Manage if needed according to PMG.
	Monitor cottony cushion scale (May) to see if the vedalia beetle is providing biological control; it is too late to relocate vedalia. If threshold is exceeded, manage later according to PMG.
	Examine twigs for citricola scale females to alert you whether management later may be needed. Be sure to distinguish citricola scale from brown soft scale.
	Look for other pests and their damage especially: ▪ Earwigs (March through June) ▪ Forktailed bush katydid (March through June) ▪ Caterpillars, including amorbia, citrus cutworm, fruittree leafroller, omnivorous leafroller, and orange tortrix. Miscellaneous pests: ▪ Ants, including fire ants and gray ants Manage if needed according to PMG.
	Look for brown garden snail. ▪ Heading into warm weather, relocation of decollates is not advised. Manage if needed according to PMG.
	Look for diseases that cause symptoms on fruit, leaves and twigs, and on limbs, trunks, and roots, especially: ▪ Dry rot ▪ Phytophthora gummosis and Phytophthora root rots Record the date and location of problem trees or sites. Manage if needed according to PMG.
	Survey weeds. Manage vegetation if needed according to PMG.

✓ Done	Petal fall activities (continued)
	Look for vertebrates, especially ground squirrels, pocket gophers, rabbits, and roof rats. Manage if needed.
	Provide proper cultural care and good growing conditions to improve tree health and fruit yield, including: ▪ Fertilize if needed. ▪ Irrigate and adjust scheduling to meet trees' varying water needs. ▪ Prune if needed, such as removing dead twigs and branches to reduce bacterial blast (citrus blast) inoculum.
	Determine whether application of plant growth regulator is warranted, such as in mandarins.
	Harvest mature fruit in coordination with other management activities to ensure good postharvest fruit quality and food safety. ▪ Educate and supervise workers regarding fruit-handling Best Management Practices (BMPs). ▪ Inspect fruit quality before bins are moved from the picking site to identify grove areas where management practices need improvement.

✓ Done	Fruit development activities (June through September) **Special issues of concern related to water quality:** Insecticide application, fungicide application, drift, runoff due to irrigation.
	Monitor California red scale males using pheromone-baited sticky traps, plus additional methods depending on the situation. ▪ Keep records of scale monitoring results. ▪ Distinguish male scales from scale parasites and other important insects caught in sticky traps. ▪ Begin checking fruit for scale infestation and percentage parasitism by *Aphytis melinus* and *Comperiella bifasciata* (July though October). o Keep records of fruit monitoring results. ▪ Release *Aphytis melinus* if biological control is compatible with the overall management program.
	Monitor fruit for immature citrus thrips (late April through June). ▪ Keep records of mite monitoring results. ▪ Examine leaves for natural enemies, such as *Euseius tularensis*. Manage if needed according to PMG.
	Monitor leaves for citricola scale nymphs (August-September). ▪ Be sure to distinguish citricola scale from brown soft scale. ▪ Keep records of scale monitoring results. Manage if needed according to PMG.
	If monitoring for cottony cushion scale adult females in May showed that the threshold was exceeded, manage according to PMG.

✓ Done	Fruit development period (continued)
	Look for citrus peelminer and search fruit for its damage. If susceptible variety of citrus, manage according to PMG.
	Monitor (August through November) for bean thrips in navel oranges if navels may be exported to Australia. Plan ahead by ordering monitoring traps. ▪ Check for revisions to regulatory export protocol, currently: adult trapping and cutting fruit preharvest and at the packinghouse. ▪ If trapping, distinguish bean thrips from other thrips species caught in sticky traps.
	Look for other pests and their damage to fruit or damage to leaves and twigs, especially: ▪ Earwigs (March through June) ▪ Forktailed bush katydid (March through June) ▪ Yuma spider mite (July through September) Manage if needed according to PMG.
	Look for diseases that cause symptoms on fruit, leaves and twigs, and on limbs, trunks, and roots, especially: ▪ Brown rot and Septoria spot fruit decays ▪ Dry rot ▪ Phytophthora gummosis and Phytophthora root rots Record the date and location of problem trees or sites. Manage if needed according to PMG.
	Survey summer weeds. Identify common summer broadleaves and grasses and sedges. ▪ Record weed survey results at least twice annually (during late winter and in summer). ▪ Look for and rouge favored weed hosts of bean thrips if navels might be exported to Australia. Manage vegetation if needed according to PMG.
	Look for vertebrates, especially ground squirrels, pocket gophers, rabbits, and roof rats. Manage if needed.
	Provide proper cultural care and good growing conditions to improve tree health and fruit yield, including: ▪ Sample leaf nutrient levels at least once mid-August through October. Fertilize if needed. ▪ Irrigate and adjust scheduling to meet trees' varying water needs. ▪ Prune if needed.

✓ Done	**Fall activities (October through December)** **Special issues of concern related to environmental quality:** drift, runoff, and volatile organic compounds (VOCs).
	Monitor California red scale males using pheromone-baited sticky traps (March through October), plus additional methods depending on the situation. ▪ Keep records of scale monitoring results. ▪ Distinguish male scales from scale parasites and other important insects caught in sticky traps. ▪ Monitor fruit for scale infestation and percentage red scale parasitism by *Aphytis melinus* and *Comperiella bifasciata* (July though October). o Keep records of fruit monitoring results. ▪ Release *Aphytis melinus* if biological control is compatible with the overall management program.
	Monitor (August through November) for bean thrips in navel oranges if navels may be exported to Australia. ▪ Check for revisions to regulatory export protocol, currently: adult trapping and cutting fruit preharvest and at the packinghouse. ▪ If trapping, distinguish bean thrips from other thrips species caught in sticky traps.
	Look for citrus leafminer (June through November) and citrus peelminer. Manage if needed according to PMG.
	Look for other pests and their damage to fruit or damage to leaves and twigs, especially: ▪ Brown garden snail ▪ Citricola scale ▪ Citrus leafminer (June through November) ▪ Potato leafhopper (September through December) ▪ Texas citrus mite (October through December) Manage if needed according to PMG.
	Look for diseases that cause symptoms on fruit, leaves and twigs, and on limbs, trunks, and roots, especially: ▪ Armillaria root rot ▪ Bacterial blast (Citrus blast) ▪ Brown rot and Septoria spot fruit decays ▪ Dry rot ▪ Phytophthora gummosis and Phytophthora root rots ▪ Rind disorder (Mandarin rind disorder) ▪ Stubborn disease Record the date and location of problem trees or sites. Manage if needed according to PMG.
	Survey weeds. Manage vegetation if needed according to PMG.
	Determine whether preventive application of certain materials are warranted including: ▪ Fruit rot, rind disorder, and twig blight (bacterial blast) protectants for diseases listed above. ▪ Plant growth regulator to reduce fruit drop. ▪ Whitewash to preserve fruit quality and to reduce fruit drop and sunburn. Treat** if warranted according to PMG.

✓ Done	Fall activities (continued)
	Provide proper cultural care and good growing conditions, including: ▪ Sample leaf nutrient levels at least once mid-August through October. ▪ Fertilize if needed. ▪ Irrigate and adjust scheduling to meet trees' varying water needs. ▪ Provide frost protection when cold threatens.
	Harvest mature fruit in coordination with other management activities to ensure good postharvest fruit quality and food safety. ▪ Educate and supervise workers regarding fruit-handling Best Management Practices (BMPs). ▪ Inspect fruit quality before bins are moved from the picking site to identify grove areas where management practices need improvement.
✓ Done	****Pesticide application checklist**
	When planning for possible pesticide applications in an IPM program, review and complete this checklist to consider practices that minimize environmental and efficacy problems. ✓ Choose a pesticide from the UC IPM Pest Management Guidelines for the target pest considering: ▪ Impact on natural enemies. ▪ Potential for water quality problems using the UC IPM WaterTox database. (For more information, see http://www.ipm.ucdavis.edu/TOX/simplewatertox.html.) ▪ Impact on aquatic invertebrates. (For more information, see *Pesticide Choice,* UC ANR Publication 8161, http://anrcatalog.ucdavis.edu/pdf/8161.pdf.) ▪ Chemical mode of action if pesticide resistance is an issue. ✓ Select an alternative chemical or nonchemical treatment when risk is high. ▪ Choose sprayers and application procedures that keep pesticides on target. ▪ Identify and take special care to protect sensitive areas (for example, waterways or riparian areas) surrounding your application site. ▪ Review and follow label for pesticide handling, storage, and disposal guidelines. ▪ Check and follow restricted entry intervals (REI) and preharvest intervals (PHI). ▪ After an application is made, record application date, product used, rate, and location of application. Follow up to confirm that treatment was effective. ✓ Consider water management practices that reduce pesticide movement off-site. (For more information, see *Orchard Floor Management Practices to Reduce Erosion and Protect Water Quality,* UC ANR Publication 8202, http://anrcatalog.ucdavis.edu/pdf/8202.pdf.) ▪ Install an irrigation recirculation or storage and reuse system. ▪ Use drip rather than sprinkler or flood irrigation. ▪ Limit irrigation to amount required using soil moisture monitoring and evapotranspiration (ET). ▪ Consider vegetative filter strips or ditches. (For more information, see *Vegetative Filter Strips*, UC ANR Publication 8195, http://anrcatalog.ucdavis.edu/pdf/8195.pdf.) ▪ Redesign inlets into tailwater ditches to reduce erosion. (For more information, see *Tailwater Return Systems*, UC ANR Publication 8225, http://anrcatalog.ucdavis.edu/pdf/8225.pdf.) ✓ Consider management practices that reduce air quality problems. ▪ When possible, choose pesticides that are not in emulsifiable concentrate (EC) form which release volatile organic compounds (VOCs). VOCs react with sunlight to form ozone, a major air pollutant.