Western IPM Center

Western Integrated Pest Management Center

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10 June 2016

Pesticide Re-Evaluation Division
Office of Pesticide Programs
Environmental Protection Agency
1200 Pennsylvania Ave NW.
Washington, DC 20460-0001

Attn: Dana Friedman for pesticide docket EPA-HQ-OPP-2008-0850
Attn: Khue Nguyen for pesticide docket EPA-HQ-OPP-2008-0351
Attn: Steven Snyderman for pesticide docket EPA-HQ-OPP-2009-0317

This comment is being provided by the Western Integrated Pest Management Center in response to dockets EPA-HQ-OPP-2008-0850 on chlorpyrifos, EPA-HQ-OPP-2008-0351 on diazinon, and EPA-HQ-OPP-2009-0317 on malathion. This comment includes information from California. Additional comments will be provided from the subregional comment coordinators of the Western IPM Center. These comments directly address the topic of use of chlorpyrifos, diazinon, and malathion as requested by the agency.

Integrated pest management (IPM) is a science-based, ecosystem level approach to pest management that identifies and reduces risks from pests and pest management using the most economical and environmentally responsible means possible. These comments on the use of chlorpyrifos, diazinon, and malathion are presented within the context of integrated pest management and mirror many of our previous comments. Data are drawn from the California Department of Pesticide Regulation's pesticide use reporting program which is one of the most comprehensive pesticide use databases in the United States.

Use of chlorpyrifos in California

For the last five years, chlorpyrifos use remained fairly steady at an average of 1,147,016 acres treated each year. In 2014, 1,103,933 acres were treated with chlorpyrifos. Chlorpyrifos products are primarily used in alfalfa, almond, cotton, walnut, and orange where these five crops account for over 75% of total acres treated (table 1).

In alfalfa, chlorpyrifos is used to control aphids (cowpea and blue alfalfa) and weevils (alfalfa and Egyptian). Chlorpyrifos controls stink bugs and leaffooted bugs in almond and codling moth and walnut husk fly in walnut. In citrus, growers use it to treat Argentine ants, Fuller rose beetle, Asian citrus psyllid, citricola scale, and citrus bud mite. In cotton, chlorpyrifos is used to control cotton aphid.

Chlorpyrifos fits into many IPM programs as an important tool for controlling invasive and persistent pests. As is the case with cowpea aphid on alfalfa and stink bug on almond, chlorpyrifos gives growers an opportunity to practice resistance management. For these two insect pests, the elimination of chlorpyrifos would leave growers with only one other mode of action. This would increase the risk of resistance development in these pests. Other arguments for the benefits of chlorpyrifos in integrated pest management programs have been provided by the Western IPM Center on a previous docket

(Appendix A). California's critical use report on chlorpyrifos identifies the pest management needs and best practices for the use of chlorpyrifos in alfalfa, almond, citrus, and cotton (Appendix B).

Table 1. Acres treated with chlorpyrifos in California from 2010 to 2014.

Crop	2010	2011	2012	2013	2014	Totals
Alfalfa	378,143.27	415,767.08	407,435.33	445,689.87	469,158.54	**2,116,194.09**
Almond	142,738.22	128,707.91	107,904.40	240,894.91	162,763.75	**783,009.19**
Cotton	125,891.93	206,841.03	107,051.69	168,842.74	98,281.21	**706,908.60**
Walnut	93,775.65	89,220.48	97,995.08	91,475.74	101,539.10	**474,006.05**
Orange	58,208.49	65,642.98	43,004.58	49,839.21	45,816.80	**262,512.06**
Sugarbeet	48,398.78	46,871.64	50,063.82	47,883.24	45,836.09	**239,053.57**
Corn, Forage and Fodder	31,719.36	48,278.70	47,889.60	54,159.60	20,949.13	**202,996.39**
Grape, Table or Raisin	26,609.08	22,183.43	26,488.73	42,777.07	34,621.09	**152,679.40**
Grape, Wine	40,391.31	15,123.77	28,359.77	20,582.71	15,174.68	**119,632.24**
Tangerine	14,538.01	22,011.23	14,485.96	15,886.31	19,106.59	**86,028.10**
Other crops	132,859.35	126,401.71	124,711.77	117,399.47	90,685.83	**592,058.13**
Totals	**1,093,273.45**	**1,187,049.97**	**1,055,390.73**	**1,295,430.87**	**1,103,932.81**	**5,735,077.83**

Sources: California Department of Pesticide Regulation pesticide use reporting program aggregated using PURwebGIS v2 from University of California, Davis.

Use of diazinon in California

Because of the use of diazinon is restricted in California crops, there has been a two-third reduction in acres treated between 2010 and 2014 (table 2). In 2014, tomato and onion accounted for nearly 40% of all acres treated with diazinon. Diazinon remains important to control maggots (seed corn and onion) and thrips (onion and western flower) in onion and to control sugarbeet wireworm and garden symphylans (*Scutigerella immaculata*) in tomato.

Table 2. Acres treated with diazinon in California from 2010 to 2014.

Crop	2010	2011	2012	2013	2014	Totals
Tomato, Processing	6,966.65	8,454.24	9,120.10	9,330.90	8,472.98	**42,344.87**
Lettuce, Head	22,957.16	11,928.83	4,642.10	435.88	970.58	**40,934.55**
Lettuce, Leaf	18,900.57	10,475.01	3,551.64	319.85	1,230.75	**34,477.82**
Cherry	13,823.37	4,840.96	3,137.25	3,567.23	1,288.02	**26,656.83**
Spinach	5,342.76	3,568.70	4,230.96	1,129.44	1,264.51	**15,536.37**
Onion, Dry	4,051.40	3,301.11	3,033.49	1,038.71	3,664.60	**15,089.31**
Pear	2,265.91	3,216.30	2,537.37	2,515.40	2,213.70	**12,748.68**
Cantaloupe	3,378.04	5,319.12	444.27	2,049.00	944.25	**12,134.68**
Apple	1,333.98	1,902.42	2,502.50	2,576.38	2,255.57	**10,570.85**
Peach	2,800.33	2,536.37	2,928.65	1,527.15	761.56	**10,554.06**
Other crops	21,417.75	15,610.13	12,429.77	10,475.36	8,895.31	**68,828.32**
Totals	**103,237.92**	**71,153.19**	**48,558.11**	**34,965.30**	**31,961.83**	**289,876.34**

Sources: California Department of Pesticide Regulation pesticide use reporting program aggregated using PURwebGIS from University of California, Davis.

Use of malathion in California

The acres treated with malathion have decreased by half since 2010 in California (table 3). In 2014, 283,943 acres were treated with malathion. Use on alfalfa accounted for 36% of total usage. Alfalfa and strawberry account for half of the total usage in California. In alfalfa, malathion controls cowpea aphid, spotted alfalfa aphid, and alfalfa and Egyptian alfalfa weevils. In strawberry, malathion is used to control cutworms (black, roughskinned, and variegated) and can be applied through the irrigation system which allows treating under plastic mulch where cutworms hide. In strawberry, malathion is also used to control lygus, spotted wing drosophila, vinegar flies, western flower thrips, and whiteflies.

Table 3. Acres treated with malathion in California from 2010 to 2014.

Crop	2010	2011	2012	2013	2014	Totals
Alfalfa	84,926.13	89,234.65	82,878.68	116,732.10	102,271.60	**476,043.16**
Strawberry	71,447.56	57,962.55	51,873.05	44,406.43	42,693.02	**268,382.61**
Orange	87,157.97	6,263.51	5,100.67	5,091.47	6,963.29	**110,576.91**
Cherry	10,101.55	21,031.79	35,812.02	19,091.02	12,617.27	**98,653.65**
Lettuce, Head	29,073.54	18,072.38	11,110.57	10,128.64	10,784.61	**79,169.74**
Broccoli	13,839.71	11,158.75	7,948.35	12,542.59	12,869.59	**58,358.99**
Lettuce, Leaf	22,748.69	11,965.07	10,248.70	5,892.97	7,200.84	**58,056.27**
Tangerine	35,228.96	3,095.62	862.67	1,609.43	2,117.32	**42,914.00**
Celery	9,556.15	8,779.93	6,535.24	5,959.06	8,260.25	**39,090.63**
Cotton	1,835.60	828.93	5,687.20	13,175.50	14,131.30	**35,658.53**
Other crops	65,395.65	52,211.94	53,177.02	54,773.77	64,033.61	**289,591.98**
Totals	**431,311.51**	**280,605.12**	**271,234.17**	**289,402.96**	**283,942.70**	**1,556,496.47**

Sources: California Department of Pesticide Regulation pesticide use reporting program aggregated using PURwebGIS from University of California, Davis.

Please contact me if further information is needed.

Sincerely,

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Appendix A. Submission to docket EPA-HQ-OPP-2015-0653 Tolerance Revocations: Chlorpyrifos

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December 17, 2015

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RE: EPA-HQ-OPP-2015-0653 Tolerance Revocations: Chlorpyrifos

This comment is being provided from the Western IPM Center in response to Docket EPA-HQ-OPP-2015-0653, Tolerance Revocations: Chlorpyrifos. This comment includes information from California. Additional comments will be provided from the sub-regional comment coordinators of the Western IPM Center.

Integrated pest management strives to find the balance between the risks and benefits associated with pests and pest management. In the case of chlorpyrifos, many of the risks to human and environmental health are known (see the risk assessment tools at ipmprime.org), but many of the specific benefits for economically sustainable agricultural production are not. Here I focus my comments on the benefits of chlorpyrifos to California agriculture within the context of integrated pest management.

Chlorpyrifos is an important tool for controlling existing and invasive pest species. Organophosphates in general and chlorpyrifos in specific have been in use for half a century, and insecticide tolerance against the acetylcholine esterase inhibitor class (carbamates and organophosphates) has occurred in pest and beneficial insect populations. Several key insect pest species continue to be effectively controlled by chlorpyrifos where newer chemistries have proven less effective. Examples from four agricultural crops and at least nine key pests are cited below. These examples were taken from the University of California Statewide IPM Program report to California Department of Pesticide Regulation which summarizes the critical uses of chlorpyrifos (available at www.ipm.ucdavis.edu/IPMPROJECT/CDPR_Chlorpyrifos_critical_use_report.pdf).

Chlorpyrifos has key uses in California alfalfa against aphids (cowpea, blue alfalfa) and weevils (alfalfa and Egyptian). In a perennial crop like alfalfa, multiple pests exceeding thresholds simultaneously is common and although alternative modes of action and cultural practices are available against individual pest species, chlorpyrifos has the advantage of controlling all of the key pests. In one case (cowpea aphid) only one mode of action, in addition to chlorpyrifos is available and removal of chlorpyrifos would risk rapid resistance development in this aphid species.

Chlorpyrifos is an essential tool in almonds because only it and pyrethroids are effective against stink bugs and leaffooted bugs. The likelihood of resistance in these pests to pyrethroids if chlorpyrifos is eliminated is unknown.

Maximum residue levels (MRLs) drive the use of chlorpyrifos in California citrus. Mid to late season treatments for Fuller rose beetle, Asian citrus psyllid, citricola scale, and citrus bud mite are possible for material destined for export because of a long standing MRL. Argentine ants are a significant problem in citrus because they protect a variety of the hompteran pests from natural enemy attack and infest irrigation lines, and chlorpyrifos is the only effective control method.

In California cotton, chlorpyrifos is the only material that will effectively control cotton aphid late in the season. For effective sweet potato whitefly adult control, it is strongly recommended that applications include chlorpyrifos to protect the quality of San Joaquin Valley cotton.

The activity of chlorpyrifos on a wide variety of insects if often considered detrimental for conservation biological control. However, there are cases where the target insect is highly susceptible to chlorpyrifos and use rates are low enough to be compatible with conservation biological control. Katydids are very susceptible to chlorpyrifos. The chlorpyrifos use rates for katydid control is low enough to preserve beneficial insects in California citrus. Beneficials might be reduced or eliminated in citrus if producers were required to use materials with higher use rates.

California is consistently under threat of new pest insect invasions and although new insecticidal products are available, many or most of these are effective against a narrow spectrum of pests. Considering that California has faced nearly one new invasive pest every year for the past decade, it would be risky to eliminate chlorpyrifos as a control tool. Used judiciously, and in cases where other control methods may not yet be available, chlorpyrifos can continue to play an important role in pest management in California.

The economic sustainability of California agriculture is reliant on the use of chlorpyrifos. Although alternative pesticides exist for several of the key pests indicated above, these alternatives can be substantially more expensive. Pesticide costs can be seven times higher than chlorpyrifos for controlling weevils in alfalfa.

In conclusion, the data above demonstrate that the benefits of chlorpyrifos in integrated pest management are significant and should therefore be considered in the decision to revoke its tolerances.

Sincerely,

Matthew Baur, Associate Director

Western IPM Center

Appendix B. California's critical use report on chlorpyrifos identifies the pest management needs and best practices for the use of chlorpyrifos in alfalfa, almond, citrus, and cotton

Identifying and Managing Critical Uses of Chlorpyrifos Against Key Pests of Alfalfa, Almonds, Citrus and Cotton




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A Report Submitted to the California Department of Pesticide Regulation

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UC Pest Management Guidelines for Alfalfa, Almonds, Citrus and Cotton were extensively drawn upon in preparing this report.

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Disclaimer

This disclaimer applies to any and all trade names seen or mentioned in the content of this report.

The use of trade names in this publication is solely for the purpose of providing information shared by the Crop Teams and other industry experts and the mention of any pesticide in this report is not a recommendation.

Always read and follow all label precautions and directions, including requirements for protective equipment. Apply pesticides only on the crops or in the situations listed on the label.

In California, all agricultural uses of pesticides must be reported. Contact your county agricultural commissioner for details for your location as laws, regulations, and information concerning pesticides change frequently.

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List of Acronyms

Abbreviation	Definition
ABC	Almond Board of California
AI	Active ingredient
BC	Biological control
BMP	Best management practices
CAFA	California Alfalfa and Forage Association
CASS	California Agricultural Statistics Service
CCGGA	California Cotton Growers and Ginners Association
CCQC	California Citrus Quality Council
CDFA	California Department of Food and Agriculture
CDPR	California Department of Pesticide Regulation
CRB	Citrus Research Board
EPA	Environmental Protection Agency
IPM	Integrated Pest Management
IRAC	Insecticide Resistance Action Committee
MOA	Mode of Action
MRL	Maximum Residue Level or Limit
NIFA	National Institute of Food and Agriculture
PCA	Pest Control Adviser
PMG	Pest Management Guideline
PUR	Pesticide Use Report
UC IPM	University of California Integrated Pest Management
USDA – FAS	US Department of Aggriculture – Foreign Agricultural Service
USDA – NRCS	US Department of Agriculture – Natural Resources Conservation Service

Executive Summary




Identifying and Managing Critical Uses of Chlorpyrifos Against Key Pests of Alfalfa, Almonds, Citrus, and Cotton

Executive Summary

Alfalfa, almonds, citrus and cotton account for over 2.5 million acres of agricultural production in California valued at over $10 billion. Alfalfa, the single largest acreage field crop grown throughout the state, is valued at $1.25 billion and provides feed for dairies, a key industry in our state. California produces almost 90% of the world almond supply, valued at over $6 billion with export to over 90 countries. California citrus is an extremely valuable commodity currently threatened by an insect-vectored bacterial disease; oranges, lemons, and tangerines are currently valued at $2 billion and this market is expected to expand. California cotton, highly regarded as the standard for premium fiber, is valued at $753 million and is one of the top ten exported commodities in the state.

Chlorpyrifos has been an important insecticide in the Integrated Pest Management (IPM) systems in each of these crops due to its efficacy, value as resistance management tool, established international registration status (MRLs), and as a tool against invasive pests and endemic pest outbreaks.

Currently there are ongoing efforts at federal and state regulatory agencies to implement regulatory measures that impact the use of chlorpyrifos. These entities are further evaluating public health and environmental concerns that could result in increased use restrictions.

The project *Identifying and Managing Critical Uses of Chlorpyrifos in Alfalfa, Almonds, Citrus and Cotton Project* was developed as a multi-year effort to identify the pest management needs and best practices for use of chlorpyrifos in these four important California crops.

To accomplish this goal, the California Department of Pesticide Regulations (CDPR) contracted with the University of California Statewide Integrated Pest Management Program (UC IPM) to convene industry leaders to work together to create commodity specific guidelines regarding chlorpyrifos use in their cropping systems. The project organized four Crop Teams (alfalfa, almonds, citrus, and cotton) to work with an appointed management team for a total of 12 professionally facilitated meetings (three meetings per team) to gather data and input on the technical and practical need for chlorpyrifos in their unique commodities and to identify critical uses for this product. The make-up of the Management Teams and the Crop Teams were specified in the CDPR contract and included industry representatives, UC Cooperative Extension specialists, pest control advisers, growers, and project staff from CDPR and UC IPM.

Through this process, the Crop Teams identified insect pests for which chlorpyrifos is presently used. Further facilitated discussions allowed the groups to more fully characterize what uses were critical, i.e., key pests for which there are no or few alternatives to chlorpyrifos, important pests for which there are alternatives and finally, occasional pests for which it is important to retain access to chlorpyrifos as a part of the IPM toolbox. It was agreed the placement in the Critical Use Matrix should not imply more or less importance of chlopyrifos, but rather the variety of options available in managing all pests. Alfalfa identified alfalfa weevils, blue alfalfa and cowpea aphids; almonds identified leaffooted bug and stink bugs; citrus identified ants; and cotton identified late season aphids and whiteflies as first tier critical uses. Alternatives to chlorpyrifos were evaluated in terms of efficacy, availability of non-chemical tactics, MRLs, cost, resistance management issues or other attributes for consideration in decision making.

While each Crop Team identified critical pests for a wide diversity of cropping systems, all agreed that chlorpyrifos is an essential element to their IPM programs to continue production and quality standards heretofore established for their commodities. They also agreed that stewardship and education are needed to ensure the safe and effective use of this product and that decision support tools are needed to assist pest control advisers (PCAs) and growers to recognize critical use scenarios that justify its application. The "new generation" of PCAs coming into the field provides an excellent opportunity to train emerging professionals about chlorpyrifos use.

The project identified specific research, extension, and policy gaps as part of an action plan to develop and adopt new pest management practices. The updated information and increased awareness will benefit growers, PCAs, and the community at large as we all work towards pest management programs that reduce risk from pests and pest management related activities.

The Crop Team participants trust that their investment in this process will assist the California Department of Pesticide Regulation as it evaluates the use of chlorpyrifos in IPM programs in alfalfa, almonds, citrus, cotton and other crops. Since the publication of the US EPA's Chlorpyrifos Preliminary Human Health Assessment in 2011, a significant amount of new research has been submitted and is currently being utilized as EPA looks to release its updated assessment by the end of 2014.

Peter B. Goodell, Ph.D., UC Statewide IPM Program, Principal Investigator

Lori A. Berger, Ph.D., UC Statewide IPM Program, Project Coordinator

Introduction

Introduction

The California Department of Pesticide Regulation's (CDPR) mission is to protect human health and the environment by regulating pesticide sales and use and by fostering reduced-risk pest management. CDPR's strategic plan includes a goal to advance the research, development, and adoption of effective pest management systems that reduce risks to people and the environment.

Chlorpyrifos is an organophosphate insecticide that has been registered and widely used for more than 40 years. It is a broad-spectrum insecticide that is an extremely valuable tool as part of an IPM program in many crops grown throughout the United States. In California, an average of 1.45 million pounds of active ingredient of chlorpyrifos products were used annually between 2002 and 2012 (CDPR PUR data).

DPR has identified potential human health and environmental risks associated with chlorpyrifos, and there is public and legislative interest in addressing concerns around chlorpyrifos use. The concerns include the risks to the environment and exposure to people, both acute and chronic. Exceedances of the water quality standards of Federal Clean Water Act in California's surface water have been documented[1,2], and programs[3] have been established to prevent and mitigate such episodes. Off-site movement caused by pesticide drift[4] has resulted in accidental exposure to workers and others[5]. Finally, concern has been raised about chronic neurotoxic damage to children[6].

In California and nationally, there is recognition that additional restrictions on chlorpyrifos use are possible. Consistent with its mission, DPR is taking a leadership role to strengthen IPM systems as part of the solution for addressing the risks associated with chlorpyrifos use.

In early 2014, CDPR contracted with the University of California Statewide IPM Program (UC IPM) to convene a diverse group of stakeholders, including scientists and other specialists, to identify critical uses for chlorpyrifos, define suites of best practices for critical chlorpyrifos applications, and develop educational materials and decision support tools for implementation of those practices. Four specific commodities were selected to work with including alfalfa, almonds, citrus, and cotton. These crops were chosen because of the role of chlorpyrifos in their IPM systems based on:

- Amount of active ingredient utilized (Figure 1.1),
- Number of crop production acres throughout the state, and
- Value of these particular commodities to the California economy.

The four crops represent $10 billion in annual revenue and cover 2.4 million acres of cropland. During the period of 2002-2012, 61% of the total chlorpyrifos use was recorded on these four crops (Figure 1.1).

The California Department of Pesticide Regulation reports that the combined use of chlorpyrifos in alfalfa, almonds, citrus, and cotton has decreased since 2006; but an increase in the amount of active ingredient applied during the period from 2009 to 2011 (although still at levels greatly reduced from 2006) is a source of public concern in connection with human health and the environment (Figure 1.1).

Although newer insecticides are also available to manage some pests in these four crops, there is a continued need to preserve the availability of chlorpyrifos for specific situations. Chlorpyrifos plays a critical role in many IPM programs for controlling pests that threaten the productivity and economic well-being of California producers and in maintaining the high quality standards required by consumers and international export markets. This active ingredient also allows production of animal feed to support the important dairy industry in California. For some pests, chlorpyrifos is one of the last effective organophosphate insecticides available and may provide an important alternative mode of action for insecticide rotations to prevent the development of resistance to newer insecticide products. For others, this product is one of very few products with international registrations with established maximum residue limits (MRLs)

[1] Starner, K. & K. Goh. 2013. Chlorpyrifos-treated crops in the vicinity of surface water contamination in the San Joaquin Valley, California, USA. Bulletin of Environmental Contamination and Toxicology 91: 287-291.
[2] Irrigated Lands Regulatory Program – Waterboards.ca.gov
[3] Coalition for Urban/Rural Environmental Stewardship. Curesworks.org
[4] Chlorpyrifos: Evaluation of the potential risks from spray drift and impact of potential risk reduction measures. EPA 2012
[5] Chlorpyrifos Exposure Incidents Related to Agricultural Use 1999-2011. California Pesticide Illness Surveillance Program (PISP).
[6] Rauh, V., S. Arunajadai, et al. 2011. 7-Year neurodevelopmental scores and prenatal exposure to chlorpyrifos, a common agricultural pesticide. Environmental Health Perspectives 119: 1196–1201.

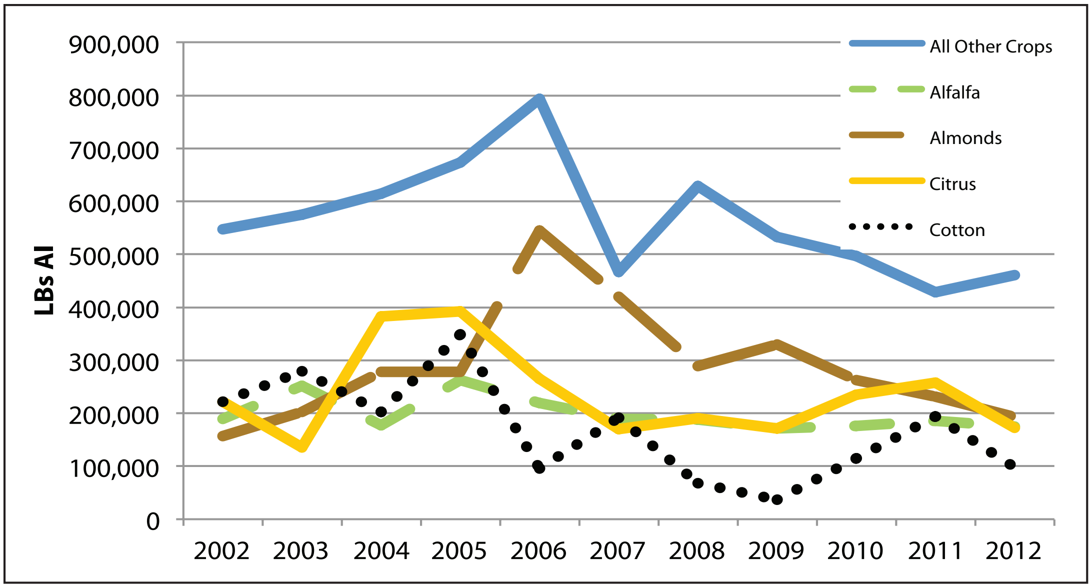

Figure 1.1. Pounds of chlorpyrifos used in California on selected crops (2002-2012).

that allow unhampered trade. Chlorpyrifos may also be a key tool for controlling invasive pests as well as endemic pests occasionally found in extremely high population densities.

The project has three phases: 1) develop an action plan to improve the management of critical uses of chlorpyrifos (this report), 2) develop educational tools to increase awareness of best management practices and promote these practices, and 3) train farmers and PCAs in these practices (Figure 1.2).

Project Objectives

Members of the California alfalfa, almond, citrus and cotton industry have worked closely with the UC Statewide IPM Program, UC scientists, farm advisors, growers, pest control advisers, commodity group representatives, and other stakeholders in a transparent participatory process of discussion and discovery to achieve the following objectives:

- *Identify critical uses for chlorpyrifos, if any, in each crop (key pests, key situations, and characterize their importance).*

- *Define suites of best practices for critical chlorpyrifos applications to help prevent and mitigate risks in each crop, as well as methods for documenting grower uses of those best practices.*

- *Produce an action plan for critical uses of chlorpyrifos in almonds, alfalfa, citrus and cotton IPM.*

- *Describe gaps in research, extension and policy that must be filled in order to develop practices that are alternatives to critical uses of chlorpyrifos, as well as additional methods for mitigating chlorpyrifos-related risks and develop an action plan to address those gaps.*

The information generated in the first phase of this project will be used to develop and extend educational products and decision support tools to promote informed decision making about best management practices including the judicious use of chlorpyrifos in IPM systems for alfalfa, almonds, citrus and cotton (Figure 1.2).

Concerns Raised by Participants

Early in the facilitated process, the opportunity was provided to the stakeholders to express their key concerns about the project. Primarily, the participants were anxious that information shared would be directly used to regulate the use of chlorpyrifos. A common concern was the fear that another effective and valuable tool would be removed, increasing the risk for crop loss.

Representatives of CDPR assured participating stakeholders that this was a process for developing technical guidance and on a separate track from regulatory rulemaking. CDPR emphasized that rulemaking to reduce chlorpyrifos risks was probable, and that it was impossible to predict what regulatory action would be taken at national and state levels or when that might occur.

Concerns Raised in Crop Team Discussions

- IPM tools would be removed
- Overly restrictive regulations might prohibit practical use of a good product
- Regulatory decision making is not based on science

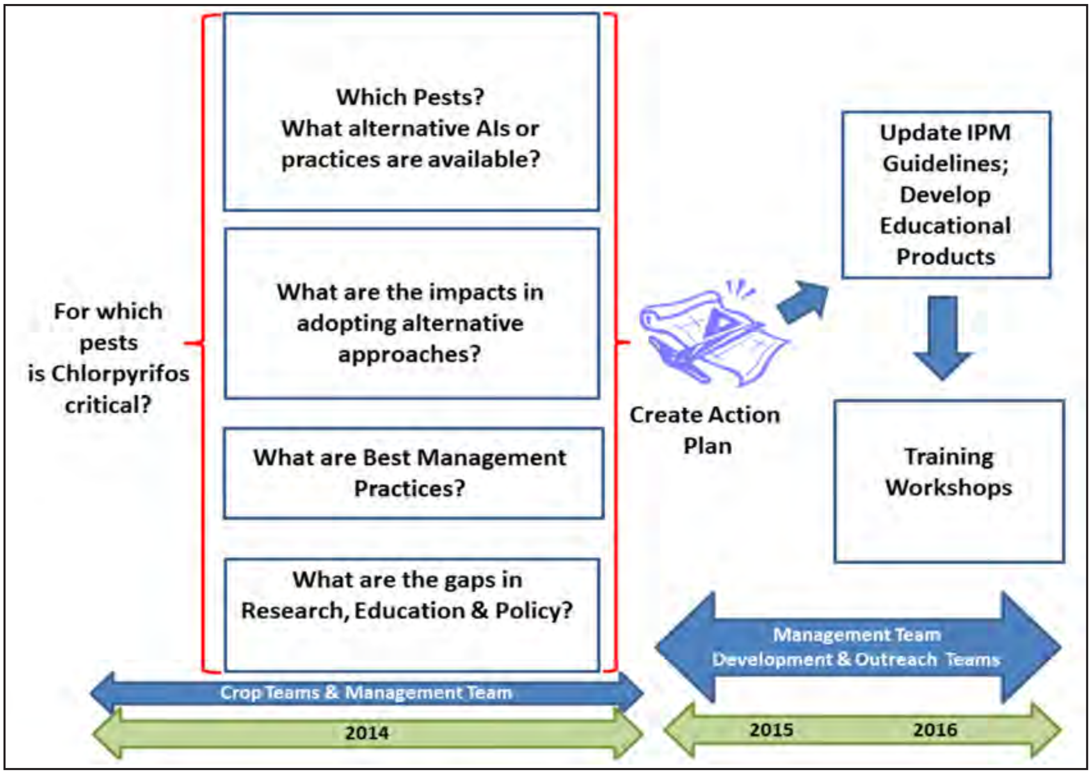

Figure 1.2. Project Schematic: "Identifying and Managing Critical Uses of Chlorpyrifos against Key Pests of Alfalfa, Almonds, Citrus, and Cotton."

Materials and Methods

Facilitated Crop Team Process

The project was built around two essential units, the Management Team and the Crop Teams whose expertise was utilized to identify critical uses. The Management Team members were responsible for identifying and enlisting experts in their crop to serve on the Crop Teams. Management Team members served as Crop Team Leaders and were responsible for communicating with Crop Team members and encouraging active participation. The Management Team defined what "critical uses" of chlorpyrifos were. Criteria included:

- *Role of chlorpyrifos in IPM programs*
- *Efficacy of chlorpyrifos versus alternative active ingredients (AIs)*
- *Impacts of alternative AIs e.g., more frequent applications, effects on pollinators and other non-target species*
- *Value of chlorpyrifos in an insecticide resistance management program*
- *Economic feasibility including cost of alternative AI or practices*
- *Impact on Trade e.g., Maximum Residue Levels (MRLs) and phytosanitary requirements for export*
- *Balancing safety issues between chlorpyrifos and alternative active ingredients*

The Management Team consisted of 10 members: Principal Investigator, Project Coordinator, CDPR contract manager and back-up, and commodity group representatives as follows: alfalfa (1 representative), almonds (2 representatives), citrus (1 representative) and cotton (2 representatives). The representatives from CDPR provided resources and information about chlorpyrifos use but did not engage in the Crop Team deliberations. UC IPM staff were responsible for management of the project and in particular served as both expert support and University liaisons, while also lending their professional credibility and industry contacts to the project.

Each Crop Team member was nominated by the Crop Team Leader. The team consisted of 8-10 members including pest control advisers (PCAs), crop consultants, growers, and an appropriate management team representative. A full roster of participants is included in the individual Crop Team reports.

Early in the discussions, the Crop Teams agreed on the Project Principles

1. Chlorpyrifos is an important tool for specific pests in an IPM program.

2. There is ongoing public concern about chlorpyrifos.

3. The job of Crop Teams is to:
    - Identify critical uses
    - Promote sound decision making when considering chlorpyrifos use in an IPM program

The professional facilitation team was contracted by the University of California Collaboration Center to develop and implement a process for obtaining consensus on the critical uses of chlorpyrifos. Facilitation, process design, and meeting organization were supervised by a professional facilitator from Ag Innovations Network[7].

The development of the action plan was accomplished through a series of three Management Team meetings and a total of twelve Crop Team meetings. Additional follow-up phone calls or conference calls were held to finalize discussions as needed by individual members that needed more time or for those that were not able to attend Crop Team meetings in person.

The first meeting, held March 18, 2014, was a joint meeting of all forum Crop Teams at the UC Kearney Ag Research and Education Center at Parlier. All other meetings were held individually at either UC Kearney Ag Research Center or at the Statewide IPM Program offices at UC Davis.

Defining Critical Use

A list of possible important pests for which chlorpyrifos is used was presented to each Crop Team to evaluate and define critical use for their pest spectrum. The following process was utilized:

• A list of pests for which chlorpyrifos is a control option in the UC Pest Management Guidelines was presented. The list was discussed to add or delete pests according to Crop Team knowledge about actual field practices.

• Next, the list of alternative active ingredients and practices was provided for each pest, discussed, and modified as needed.

• The Crop Team reviewed alternative pest management options and discussed their value and practicability in managing pest outbreaks including biological and cultural practices (e.g. crop sanitation or use of tolerant cultivars).

• The Crop Team noted any strengths and weaknesses of alternative options, including risk to environment, human health, and profit.

• Finally, the Crop Teams were asked to identify gaps in research, education, and policy which impact selection of crop protection tools or strategies.

After a series of iterations and review, each Team was presented with the final list and asked to define where each pest would reside in the criticality continuum. Much discussion was generated about how the results should be presented and it was agreed the placement in the Critical Use Matrix should not imply more or less importance, but rather the extent of other options one has in managing key and occasional pests.

Collection of Cost Data for Relative Pricing Estimate

The topic of product pricing and relative cost was raised several times during the Crop Team discussion. There was agreement that a broad understanding of product costs might provide useful information to further support discussions and characterization of critical uses of chlorpyrifos.

The Crop Teams approached this activity with a clear understanding that pricing is quite variable according to markets served (e.g. field crops versus orchard) and the size of retail operations (major operation or local establishment) and that pricing is often subject to volume discounts to large growers and farming operations. As such, this information was collected simply to develop base-line estimates for comparison with the cost of using chlorpyrifos.

Pricing information was solicited from a total of 6 vendors of agricultural products with a commitment that sources for all data would remain anonymous and confidential. Participants were selected to represent a wide array of regionality and size of retail operation. Costs for over 70 different active ingredients were requested from each vendor. These included several formulations of chlorpyrifos, alternatives to chlorpyrifos and generic products when available. Not all vendors carried all products due to local markets or limitations of product offerings. Data were collected and averaged to a standardized common unit cost for each active ingredient, e.g. fluid or dry ounce.

[7] Ag Innovations Network 101 Morris St, Ste 212, Sebastopol CA, 95472

To develop a relative cost ratio, the "Pest by Active Ingredient" table (Appendices 3-6) developed by the Crop Teams was used. The high and low application rates per acre for each active ingredient were determined by consulting the UC Pest Management Guidelines (PMG)[8] for alfalfa, almonds, citrus, and cotton or the product label[9] for each crop and pest situation. These rates were multiplied by the common unit cost and average to get a cost/acre. The relative cost was determined by dividing the alternative active ingredient AI average cost/ac by the average cost per acre for chlorpyrifos, the lower the ratio, the less expensive the alternate insecticide was compared to chlorpyrifos. For more details, see Appendix 7. For example, for a specific pest on a specific crop:

- *Product A average cost per acre was $2.00*
- *Chlorpyrifos average cost per acre was $1.50*
- *The relative cost ratio would be 1.33, or 33% more costly to use the alternative.*

This calculation was performed for each pest for each crop for each active ingredient and can be found for each pest in the Pest Profiles.

During the collection of these data, the following situations occurred:

- *Cases where chlorpyrifos is not specifically labeled for some specific target pests, however, its use is allowable according to section 6000 of the California Code of Regulations (Title 3 Food and Agriculture, Division 6). These situations are noted throughout the Pest Profiles. Since no rates were available for comparison,.*

- *In some cases, alternative AIs were not labeled for specific pests and therefore, no rate information was available. These situations are marked as NA, not available.*

- *In a few cases, information on price could not be obtained and the situations were marked as NA.*

- *Finally, some AIs may not be included in PMG lists for several reasons, including lack of information on efficacy or determined by UCCE experts that it was not optimum fit in an IPM program for that pest/crop/timing combination.*

[8] *www.ipm.ucanr.edu.*
[9] *www.agrian.com.*

Pesticide Use Data

Pesticide use data was provided by California Department of Pesticide Regulation from their extensive pesticide use reporting database (PUR). A subset of the database was provided as an Excel database containing 72,145 individual use records of chlorpyrifos use on alfalfa, almonds, citrus, and cotton in individual counties by date from 2002 to 2012. The number of pounds active ingredient (AI) and cumulative acres treated were the primary data utilized for analysis in this report.

Results and Discussion

Science-Based Pest Management

For the purpose of this report we, will utilize the definition of Integrated Pest Management (IPM) proposed by the National IPM Program in USDA

NIFA[10] because it specifically addresses "science-based decision making," raised by the Crop Teams throughout this project. This definition recognizes that risk can arise from both pests and pest management activities while emphasizing multiple approaches.

The Crop Teams agreed that the underlying foundation of their discussions about chlorpyrifos use was the premise that good IPM practices were already being utilized. Foundational activities include frequent scouting, proper identification, use of recognized decision thresholds, consideration of options, informing the client of any mitigating activities required by the

Integrated Pest Management

Integrated Pest Management (IPM) is a science-based, decision making process that identifies and reduces risks from pests and pest management related strategies.

IPM coordinates the use of pest biology, environmental information, and available technology to prevent unacceptable levels of pest damage by the most economical means, while minimizing risk to people, property, resources, and the environment.

National Roadmap for Integrated Pest Management

Revised October 1, 2013

pesticide label, consideration of all alternative management options, and selection of the most appropriate insecticide, if needed.

Since 1972, California has required a licensed professional to dispense advice on pest control in agriculture. Through the Pest Control Adviser (PCA) licensing process a cadre of dedicated professionals has been developed. Through certification by exam and continuing educational requirements, the PCA provides expertise in field scouting, pest population assessment, and recommendations for pest control or management.

Key to the PCAs activities is their understanding of IPM and consideration of *"alternatives and mitigation measures that would substantially lessen any significant impact on the environment."*[11] In addition, the UC IPM Program maintains Pest Management Guidelines[12] which provide keys to pest identification, description of the damage, and cultural, biological, and chemical practices for management. For each pest, the list of suggested insecticides is ranked by their fit within an IPM program and provides additional information for mitigating human and environmental risks.

Once a decision has been reached to treat with an insecticide, there are many products available. In choosing any particular product, the following must be considered by the PCA:

- *Efficacy*
- *Length of residual control*
- *Impact on the natural enemy complex and other nontarget species*
- *Pre-harvest interval*
- *Worker reentry times*
- *Spectrum of pests being managed*
- *Current status of insecticide resistance of pest(s)*
- *Local conditions*
- *Sensitive areas*
- *Degree of threat to crop*
- *Other production activities which could interfere with application*
- *Maximum residue limits (MRLs) established for exported commodities*

Critical Use Matrix

The four Crop Teams reviewed over 50 pests and over 70 insecticide AIs. They categorized these pests into three tiers of criticality:

- ***Key pests*** *with no or few alternatives insecticides*
- ***Important pests*** *with alternative insecticides*
- ***Occasional pests*** *with alternative insecticides*

It is important to report in this process, that all Crop Teams emphasized the position of any particular pest in the group did not suggest a lack of importance of a pest. In other words, this categorization is not intended to suggest unimportant uses but rather that some uses have few or no alternatives. The objective of the industry discussion was to identify pests and circumstances where chlorpyrifos plays a major role in an IPM program.

The three tiers constitute the Critical Use Matrix (Table 1.1) and represent places on a continuum of criticality. In Tier 1, key pests with few or no insecticide alternatives were pests which, if not managed with chlorpyrifos, would result in substantial loss in crop value. Chlorpyrifos serves as the primary response when populations exceed recognized damage thresholds. This is an area in which educational opportunities to recognize these pests, proper scouting and assessment, and an understanding of mitigation obligations should be highlighted.

Crop	Tier			Total Pests Identified
	1 Key Pests with No or Few Alternative Active ingredients	2 Important Pests with Alternative Active Ingredients	3 Occasional Pests with Alternative Active Ingredients	
Alfalfa	3	3	4	10
Almonds	2	6	4	12
Citrus	2	12	0	14
Cotton	2	4	4	10

Table 1.1. Summary of criticality of chlorpyrifos against insect pests in four crops.

[10] *National IPM Roadmap. 2013. National Institute of Food and Agriculture: www.csrees.usda.gov/nea/pest/in_focus/ipm_if_roadmap.html.*
[11] *Flint, ML. 2012. IPM in Practice. 2nd ed. UC Ag and Natural Resources Publication 3148. 292 pages.*
[12] *www.ipm.ucanr.edu*

Crop	Low	High
Alfalfa	0.31	7.60
Almonds	1.16	4.45
Citrus	0.11	7.67
Cotton	0.27	5.68

Table 1.2. Range of relative costs per acre of alternative AIs. If the average cost per acre is equal to the price of chlorpyrifos, the value would be 1.0.

Tier 2 represented important pests that frequently cause substantial loss but alternative insecticides are available. In some situations, chlorpyrifos is the best choice because of multiple pests occurring simultaneously or extenuating circumstances provide a best fit for chlorpyrifos. Details are provided in individual Pest Profiles in each crop section. These pests offer the educational opportunity for scouting and assessment, recognition of importance of alternative insecticides in order to reduce overall risk and preserve chlorpyrifos for exceptional circumstances, and providing a stepwise decision tree for considering treatment options.

Insect pests in Tier 3 are occasional pests that can cause problems. There are insecticide alternatives, but chlorpyrifos may be needed to manage an exceptional outbreak. These pests also might offer the most opportunity to re-evaluate pest management strategies and adjust product choices. For details on each pest, refer to Pest Profiles in each crop section.

Cost of Alternative Active Ingredients (AIs)

Crop protection retailers provided price estimates for nearly 100 products covering 72 active ingredients. There were a total of 249 responses from 7 retailers. The complete list can be found in Appendices 1-2. A wide range of relative costs of alternative AIs were noted in each of the four crops (Table 1.2). Relative cost ratios for individual products and pests can be found in the Pest Profiles sections under each crop. A summary for each crop is located in the individual chapters.

During the Crop Team sessions, each Team was asked if lower cost is the driving factor in chlorpyrifos use. Overwhelmingly, the response was that efficacy was the key driver, regardless of the cost differential. However, cost was a factor in situations where a pest outbreak was sustained and required multiple insecticide applications to prevent loss or multiple pests were present simultaneously which could be controlled with chlorpyrifos.

Best Management Practices to Mitigate Potential Risk from Chlorpyrifos

Concern about chlorpyrifos moving off-site has resulted in the development of a wealth of information. Whether by inadvertent drift off the field or movement in runoff water from the field, there are many practices already established to prevent these events. In addition to information, there are several organizations that support growers and PCAs in ensuring that the active ingredient goes to the target site and nowhere else.

In the forefront of ensuring compliance with the Federal Clean Water Act are regional water boards. Chlorpyrifos has been identified as one pollutant which impairs the quality of California's water bodies. In 2003, as part of the Conditional Ag Waiver, farmers banded together into coalitions which monitor and analyze the water quality of their respective sub-watershed and facilitate the implementation of management plans. A management plan goal is to reduce agricultural impacts on water quality, evaluates the frequency and magnitude of exceedances and prioritizes outreach to improve management practices.

There are numerous practices available to prevent runoff and drift of chlorpyrifos off-site and a full discussion is not possible to make in this limited report. The Crop Teams clearly support basic IPM approaches of proper pest identification, use of knowledge of pest biology, scouting, sampling and consideration of all approaches, including biological, cultural and chemical. If a chemical pesticide is needed, the lowest risk and most effective product should be selected using tools from the UC IPM Pest Management Guidelines. The following are presented by Prichard et al. [12] to manage offsite movement of agricultural chemicals:

Avoid Drift

- *Handle pesticides to reduce risks to water quality*
- *Be aware of application conditions such as weather*
- *Maintain application equipment in excellent condition*
- *Regularly calibrate equipment*
- *Use buffer zones*
- *Select optimal application method, air vs. ground*

Avoid Runoff

- *Operate irrigation systems to apply sufficient water without causing field runoff*
- *Consider using pressurized systems versus gravity fed systems*
- *Schedule irrigation to the crops needs*
- *Improve water infiltration*
- *Manage soil organic matter to reduce runoff*
- *Consider use of water recirculation systems*
- *Avoid treatments prior to a storm event that could result in runoff*

Details for these and other management practices can be found in additional resources listed in Appendix 11.The UC Statewide IPM Program has a number of tools available to help plan and manage the use of chlorpyrifos.

For example, in each Pest Management Guideline, there is an option to review products and the threat to water. WaterTox, is an example of application of USDA-NRCS WinPST (Windows Pesticide Screening Tool) which can be used to very specifically evaluate the risk to water resources, if present. An additional tool, useful in planning a Year-round IPM program is the Step-by-Step Process for Developing the Pest Component of a NRCS Conservation Plan. (See Resources section at the end of this report).

The NRCS Process:

1. *Identify current pest management activities on the farm*
2. *Identify any risks to the environment associated with pest management practices*
3. *List alternative practices to current pest management program including cultural, biological and chemical. Consider NRCS list of 595 Pest Management practices*
4. *Plan and implement practices using a year round approach*

While the tool was initially designed to support NRCS Conservation Planning, this approach adapts easily to a water management plan as well.

These resources are examples of how PCAs and growers can be supported in documenting the process of deciding to treat, considering alternative practices and active ingredients, and mitigating the risk if chlorpyrifos is used. These will be extremely useful as this project advances to developing outreach tools specific to chlorpyrifos.

Alternative Management Practices

IPM programs use information on the life cycles of pests and their interaction with the environment. Tactics which may reduce or eliminate the need for insecticides, including chlorpyrifos, are called "Alternative Practices" which limit the buildup of pests or reduce habitat.Examples include use of resistant varieties, mating disruption, field sanitation, conservation of natural enemies, pruning, weed control and many more.

Alternative practices for critical pests were discussed by each of the Crop Teams. This information, when available, was included as a part of the Pest Profile for each species. For an expanded list of examples of alternative practices, see "General IPM" in the Resources section at the end of this report.

[12] *Prichard, T., M. Canevari and L. Schwankl. (in press). Controlling offsite movement of agricultural chemical residues – Alfalfa. 58 pp. UC ANR Publications.*

Alfalfa Crop Team Report

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Overview

Through a facilitated process, the Alfalfa Crop Team identified 10 insect pests for which chlorpyrifos was important and which required growers' continued access to it. Of these pests, chlorpyrifos is imperative for aphid control and will remain vital until such time as new, effective controls are registered for use in alfalfa production. Weevil control without chlorpyrifos would rely heavily on a limited number of pesticide options, increasing the potential for resistance and exposing growers to extensive losses. The importance of this active ingredient for management of aphid and weevil control does not diminish its importance in controlling the other identified pests at certain times and situations. IPM practices are in wide use throughout California including sampling pest populations, assessing the threat to yield and quality and choosing selective and/or reduced risk insecticides when available. The industry depends on host-plant resistance and conservation of natural enemies as alternative management approaches to insecticide use. Practices that mitigate risks from chlorpyrifos use are implemented.

Introduction and Background

In 2012, California alfalfa growers produced $1.38 billion revenue from 950,000 acres of land, averaging 6.9 tons per acre. Alfalfa is produced in a wide range of climatic environments from the Mexican to the Oregon border, from the coastal valleys to the mountain valleys. There are six alfalfa production regions identified in California; Intermountain, Sacramento Valley, San Joaquin Valley, Coastal, High Desert and Low Desert (Figure 2.1). The area with the largest alfalfa footprint is the San Joaquin Valley.

To meet this diversity of climatic locations, California grows the full range of fall dormancy alfalfa varieties. Fall dormancy ratings range from non-dormant (actively growing in winter) in the southern deserts to semi-dormant in the Central Valley to dormant in the Intermountain north. There are about 9 cuttings in the Low Desert area and an average of 6-8 cuttings in the Central Valley, and 3-4 cuttings in the Intermountain Region. Cuttings generally occur between 28-37 days in the warmer regions and 30-45 days in the cooler intermountain area.

Alfalfa is primarily used as feed for dairy cows as well as a wide variety of other livestock. It is mainly utilized as hay, but sometimes green chopped, ensiled, or made into dehydrated pellets or cubes. Occasionally it is directly grazed as well. Alfalfa is utilized by neighboring states as well as exported to Asia and the Middle East.

Figure 2.1. Alfalfa production regions in California.

Alfalfa holds a unique position in the cropping landscape. It is a semi-perennial crop grown for its foliage and maintained in a vigorous vegetative never allowed to go into reproductive maturity. It is available year round as habitat for a diverse collection of beneficial insects and has been called the "insectary" for natural enemies, which move in and out of alfalfa into neighboring crops when fields are harvested.

Alfalfa Integrated Pest Management (IPM)

Alfalfa has a long history with and deep ties to IPM. In the late 1940's UC Berkeley entomologists first developed the basic concepts of scouting and treatment decisions based on pest numbers in the alfalfa. In the late 1950's the Integrated Control Concept was first developed in this crop, the basic tenets of which are the foundation of IPM programs today.

Host plant resistance plays a key role in the alfalfa IPM program, especially for aphid management. However, host-plant resistance is not complete because resistance is measured in a population of plants and one alfalfa plant is not a clone of the next. An alfalfa variety is considered to be highly resistant to a pest or disease when more than 50% of the plants display the trait.[1]

[1] *National Alfalfa and Forage Alliance. 2014. https://www.alfalfa.org/varietyLeaflet.php.*

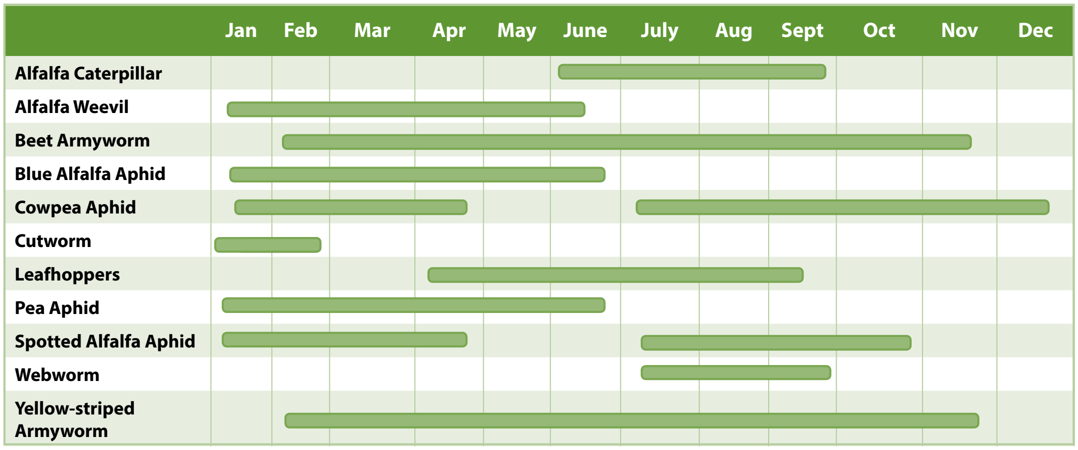

Figure 2.2. Seasonality of important alfalfa pests.

Conservation of natural enemies is an important consideration in the decision-making process and particularly as part of worm and aphid pest management assessments.

There is a wide range of insect pests in alfalfa against which chlorpyrifos is used (Figure 2.2). In many instances, multiple pests occur simultaneously. For example, if two or three leaf feeding worm species were present at one time, the decision to treat should be based on the cumulative damage in order to prevent loss. In many instances, multiple species of aphids, as well as weevils, might appear at the same time, altering the choice of an insecticide combination to manage the pest complex.

Pest management practices do not differ greatly between production regions, but the occurrence and severity of pests do differ. Details of seasonal occurrence and management of these insect pests can be found in the Year Round IPM Program at UC IPM Pest Management Guidelines for alfalfa hay[2].

For example, several aphid pests can occur through the year, depending on location (Figure 2.2). In addition to direct feeding damage, aphids can inject toxins that stunt the plant and can impact later cuttings by reducing growth and productivity. Aphid outbreaks are unpredictable but may be related to seasonal weather patterns. The use of resistant alfalfa varieties and naturally occurring biological control are the foundations of aphid pest management.

Alfalfa weevils are key pests in late winter to early spring when they can build to high numbers and damage growing tips and leaves. This damage can result in reduced yield and quality. Lepidopteran pests, including alfalfa caterpillar, armyworms, and in the high desert area, webworms, feed on alfalfa leaves. Other occasional pests for which chlorpyrifos has a role are leafhopper and cutworm.

The number of active ingredient registrations for alfalfa generally lag behind other crops. For example, there are no neonicotinoids products registered, which are useful against aphids and more selective than current insecticide choices.

[2] *www.ipm.ucanr.edu*

Criticality of Chlorpyrifos in Alfalfa IPM

Chlorpyrifos is one of many active ingredients on which pest managers and growers rely (Appendix 3). During the process of identifying critical uses, 10 insect pests were identified (see Table 2.1). Of these, three were considered **Key pests** with no or few alternative products, three were considered **Important pests** but alternative active ingredients were available, and four were considered **Occasional pests** with alternative active ingredients available. In addition to the number of insecticide alternatives available, the number of alternative practices available was an important consideration. These are listed for each pest in Pest Profiles including cultural (e.g. host plant resistance) and biological controls.

Critical Uses of Chlorpyrifos in Alfalfa			
Criticality Tier	**Pest**	**Number of Modes of Action in Addition to Chlorpyrifos**	**Alternative Practices Available**
Key Pests with Few or No Alternatives	Weevil (Alfalfa and Egyptian)	3	No
	Blue Alfalfa Aphid	2	Yes
	Cowpea Aphid	1	No
Important Pests with Alternative	Alfalfa Caterpillar	5	Limited
	Armyworm (Beet and Yellow-Striped)	5	Limited
	Pea Aphid	1	Yes
Occasional Pests with Alternatives	Cutworm	3	No
	Leafhoppers	3	No
	Spotted Alfalfa Aphid	2	Yes
	Webworm	4	No

Table 2.1. Critical uses of chlorpyrifos in alfalfa. Modes of action refer to the Insecticide Resistance Action Committee (IRAC) classification (www.irac-online.org).

Chlorpyrifos Use Pattern

According to data from CDPR Pesticide Use Reports during the period 2002-2012, total chlorpyrifos use has level remained at about 125,000 - 200,000 lbs. per year between 2002 and 2012 (Figure 2.3). The pounds of active ingredient per treated acre held steady at an average of 0.47 lbs ai/ac during the period from 2002 to 2012. On average, 79% of applications were made by air with the remainder by ground application (CDPR PUR data) and 35% of the total acres were treated with chlorpyrifos (Appendix 8).

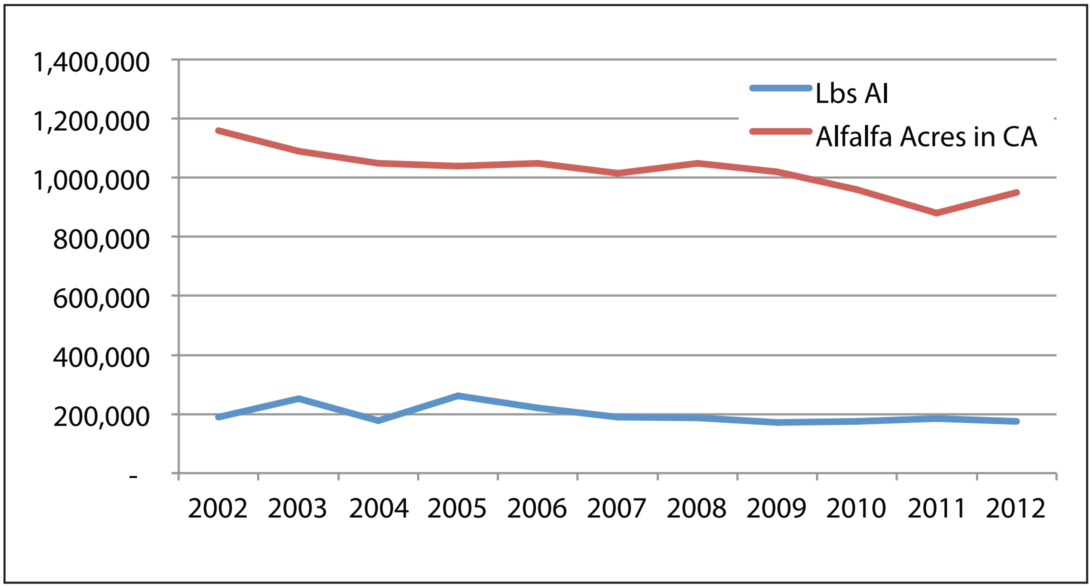

Figure 2.3. Pounds of chlorpyrifos use and and acres of alfalfa in CA (2002-2012).

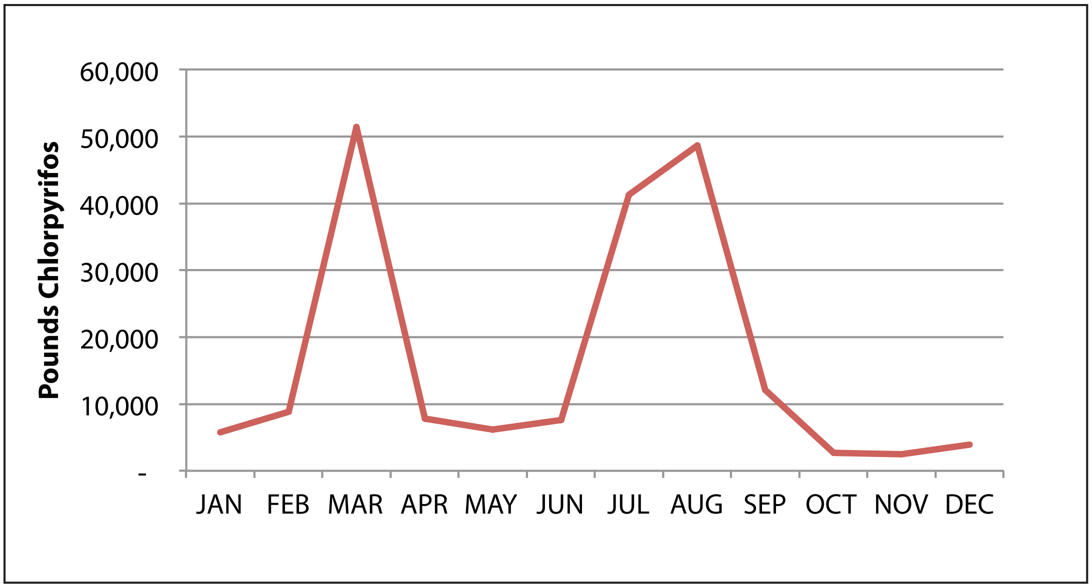

Figure 2.4. Chlorpyrifos use in alfalfa by month (2002-2012).

There is a marked bimodal pattern in monthly use with peaks in March and August (Figure 2.4). The peak in spring reflects weevil and aphid management, which supports the finding that chlorpyrifos use is critical to control these pests. The summer peak is due mostly to worm outbreaks, including alfalfa caterpillar and western yellow striped and beet armyworms, represents 46% of the average annual usage. This pest complex was identified Important but alternative active ingredients are available, indicating an opportunity where reduction in chlorpyrifos use is possible. The Crop Team emphasized the importance of chlorpyrifos in managing key and occasional pests in alfalfa production. They note that alfalfa lacks a number of important active ingredients for aphid control, especially neonicotinoids. The dearth of active ingredients effective against coleopterans (weevils) was also highlighted.

It was noted by the Crop Team that pyrethroids have been used alone for weevil and aphid control. If aphids develop a tolerance or resistance to this class of compounds, the absence of parasitoids caused by pyrethroids could create an environment for aphid populations to explode. The negative impact of pyrethoids on parasitic wasps and other predators which are important for biological control of aphids is one of the main reasons they are not listed in UC PMGs for aphids in alfalfa.

Cost of Alternative Active Ingredients

The cost of alternative active ingredients relative to chlorpyrifos depended on cost per unit of product and the recommended rates per acre. Table 2.2 presents the relative costs of alternative AIs to chlorpyrifos for control of alfalfa pests. The range of relative costs varied between a low 0.31 the cost of chlorpyrifos to a high of 7.60 Details of alternative active ingredients can be viewed individually in the Pest Profiles section.

Tier	Pest	Low	High	Comments
1	Blue Alfalfa Aphid	0.41	3.17	Resurgent pest in recent years, no narrow spectrum AIs; tolerant cultivars important
	Cow Pea Aphid	0.41	1.23	Newest aphid introduction, no narrow spectrum AIs; no tolerant cultivars
	Alfalfa Weevil	1.22	7.60	Few active ingredients designed for beetles
2	Alfalfa Caterpillar	1.00	4.35	Selective alternative AIs available
	Pea Aphid	0.41	1.23	No narrow spectrum AIs; tolerant cultivars useful
	Armyworms	1.10	3.57	Selective alternative AIs available
3	Spotted Alfalfa Aphid	0.41	1.23	Cultivar resistance is primary management tool
	Cutworm	0.31	3.89	None
	Leafhopper	0.62	2.91	None
	Webworm	0.33	2.78	Primarily high desert area pest
	Summary	**0.31**	**7.60**	

Table 2.2. Relative costs of alternative AIs compared to chlorpyrifos products in alfalfa. If the average cost per acre is equal to the price of chlorpyrifos, the value would be 1.0.

Gaps in Research, Extension and Policy

The Crop Team identified the following research, extension and policy needs relative to chlorpyrifos use. These are in no particular order.

Research

• Prioritize evaluation selective insecticides to manage blue alfalfa aphid, other aphids and weevil species in efficacy research programs

• Register new products with alternative modes of action to manage blue alfalfa aphid, other aphids and weevil species

• Conduct research to evaluate and refine practices to manage blue alfalfa aphid, other aphids and weevil species

• Validate and/or assess stability of host-plant resistance to blue alfalfa aphid

• Develop alfalfa varieties with host plant resistance against alfalfa pests

• Develop information on crop stage development relative to pest management decisions

• Evaluate for spot treatment rather than broadcast applications for alfalfa pests

• Establish weevil research to improve efficacy and adoption of bio-control agents

• Conduct weevil research to understand biology and life cycles, e.g. how many generations actually occur

• Improve the sampling protocols for aphids, weevils and worms

• Develop information on pest biology to improve understanding of the importance of different insect life stages when making treatment decisions

• Assess the value and role of alfalfa as a major component of regional landscape management and pest management systems

Extension

The University of California has had a strong alfalfa extension education programs utilizing a diversity of outreach methods including presentations at production meetings, annual symposium, web pages (UC IPM guidelines and alfalfa websites), books (Alfalfa IPM manual, production manuals), one-page factsheets, field days, and blogs. Information specific to chlorpyrifos can be readily incorporated into these outreach programs and products. A full list of resources is provided in Appendix 11. Recommended future outreach activities or objectives related to chlorpyrifos stewardship include:

• Revise PMGs to reflect increased value of alfalfa

•Improve explanation of pesticide lists in PMGs and clearly explain why some AIs are not included

• Improve the overall timeliness of PMGs to stay current with research and insecticide registrations

• Highlight the complex of variables PCAs must take into account prior to making an insecticide recommendation in alfalfa

• Develop educational tools for identification of immature stages of insects

• Develop outreach materials that highlight the value and management of indigenous biological control in an alfalfa field

• Improve information exchange between PCAs, growers and extension to track regional pest outbreaks

"There are a lot of variables involved in alfalfa treatment decisions and product selection including pest complex, life stage(s), crop stage, time of year, environmental conditions and the end use of the hay, to name just a few."

"An absence of selective insecticides for alfalfa is placing undue reliance on a few AIs, such as chlorpyrifos."

Policy

• Registrants and Distribution Chain: Increase the number of AIs being registered for alfalfa in California

• US EPA: Ensure MRLs (maximum residue limits) are established for all pesticides used in alfalfa bound for export markets

• CDPR and EPA: Expand exemption criteria to include benefits and implications of additional AIs on IPM and for resistance management (i.e., beyond economics)

• Consider adding the "Target Pest" as a reportable category in the PUR system to improve understanding of pesticide use trends

• University of California: Evaluate and assess the value of increasing research and extension academics in agronomic crops, including alfalfa

• University of California: Assess the value of providing an independent IPM funding source to respond to current and future IPM challenges, especially in crops like alfalfa where funding opportunities are extremely limited

• Alfalfa and Forage Industry Organizations: Strengthen relationship with dairy industry in supporting alfalfa research by demonstrating the value of alfalfa research to the dairy supply chain

Potential Funding Sources for Alfalfa

The Alfalfa Crop Team identified potential sources of funding to support research and outreach projects related to chlorpyrifos use in IPM systems.

Source	Organization and/or Program
Commodity	California Alfalfa and Forage Association
State	CA Department of Pesticide Regulation - Research Grants and Pest Management Alliance Grants California Department of Food and Agriculture
Federal	EPA USDA Crop Protection and Pest Management (CPPM) USDA Pest Management Alternatives (PMAP) USDA Integrated Organic Program (IOM) USDA National Extension Integrated Pest Management Projects Program (EIPM) USDA NRCS Natural Resource Conservation Service (NRCS) USDA Sustainable Agriculture Research and Education (SARE)
Regional	Western Region IPM Center - Work Groups and Pest Management Strategic Plans
Corporate	Pesticide manufacturers Seed companies Farming organizations Dairy industry

Best Management Practices (BMPs) to Mitigate Risks of Chlorpyrifos Use in Alfalfa

When planning for possible chlorpyrifos applications in an IPM program, consult the UC IPM Guidelines and consider the following Best Management Practices. For additional information, refer to the "Resources" section at the end of this document.

Consider water management practices that reduce pesticide movement off-site.

- ☐ Install an irrigation recirculation or storage and reuse system. Redesign inlets into tailwater ditches to reduce erosion.
- ☐ 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.
- ☐ Install sediment traps.
- ☐ Apply polyacrylamides in furrow and sprinkler irrigation systems to prevent off-site movement of sediments.
- ☐ Redesign inlets and outlets into tailwater ditches to reduce erosion.

Consider practices that reduce air quality problems.

- ☐ When possible, reduce volatile organic compound (VOC) emissions by decreasing the amount of pesticide applied, choosing low-emission management methods, and avoiding fumigants and emulsifiable concentrate (EC) formulations.
- ☐ Use the Department of Pesticide Regulation calculators to determine VOC emission rates from fumigant and non-fumigant pesticides.

Choose a pesticide from the UC IPM Alfalfa PMG for the target pest, considering:

- ☐ Impact on natural enemies and honey bees.
- ☐ Potential for water quality problems using the UC IPM WaterTox database.
- ☐ Impact on aquatic invertebrates.
- ☐ Chemical mode of action, if pesticide resistance is an issue.
- ☐ Endangered species that may be near your site.

Before an application:

- ☐ Ensure that spray equipment is properly calibrated to deliver the desired pesticide amount for optimal coverage.
- ☐ Minimize off-site movement of pesticides.
- ☐ Use appropriate spray nozzles and pressure.
- ☐ Avoid spraying during conditions conducive to drift or runoff.
- ☐ Identify and take special care to protect sensitive areas surrounding the application site.
- ☐ Review and follow labeling for pesticide handling, personal protection equipment (PPE) requirements, storage, and disposal guidelines.
- ☐ Check and follow restricted entry intervals (REI) and preharvest intervals (PHI).

After an application:

- ☐ Record application date, product used, rate, and location of application.
- ☐ Follow up to confirm that treatment was effective.

Pest Profiles

As a part of the critical use discussions, the Alfalfa Crop Team identified a list of important pests for which chlorpyrifos is considered an important pest management tool.

In order to characterize these pests, general information on the role of this product in IPM, damage, seasonality, frequency and severity of pest outbreaks has been summarized for each species. In addition, information on cost and effectiveness of alternative products and management practices for each pest were assembled in order to have a basis for evaluation and comparison.

This information has been presented in a standardized format simply to describe the role of chlorpyrifos in IPM for the purpose of this project. For detailed information on pest biology, damage and pesticide usage, the UC IPM Pest Management Guidelines for alfalfa production and CDPR Pesticide Use Report are recommended.

The following section presents the alfalfa pests identified by the Alfalfa Crop Team. The pests are presented in order of the criticality ranking determined by the team.

Weevils (Alfalfa and Egyptian Alfalfa)

Hypera postica and H. brunneipennis

Weevils are key pests in alfalfa IPM systems. Young larvae damage the plant by their feeding on terminal buds and leaflets. Mature larvae cause the most damaging by skeletonizing and bronzing of the leaves in late winter or spring (precise timing depends on location). Under severe pressure complete defoliation can occur. Damage from weevils is most commonly seen at the first cutting, but damage may also occur on the second cutting or under extreme pressure third cutting as well. Sometimes weevils are concentrated under windrows, stunting the growth of the new crop. Weevils overwinter as adults in field trash or other secluded hiding places in the alfalfa field and become active with increasing temperatures in late winter or early spring, depending on the location. Soon after emergence and mating, the adult females begin inserting their eggs into alfalfa stems. After hatching, larvae make their way up the stem to feed on alfalfa terminals, mature and drop to spin a cocoon and pupate by early to mid-summer.

Weevils are considered to have one generation per year in most of its California range but evidence is mounting that a second generation (or even more) occurs in the San Joaquin Valley.
Pyrethroid products work well on weevils and have some efficacy against aphids. Over time, this can become a problem, as aphids may evolve resistance to pyrethroids and natural enemies being compromised by pyrethroid use.

Role of Chlorpyrifos: Chlorpyrifos is an important active ingredient to manage alfalfa weevil. Few active ingredients are available that are effective against beetle pests. Chlorpyrifos can be especially important when the alfalfa plant is very short and weevils are destroying growing tips. Only one application per cutting is allowed. The total amount of active ingredient allowable per season varies among chlorpyrifos products. This active ingredient is useful when multiple pests are present, such as when weevils and aphids co-occur.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Potential for severe damage
Damage	Foliar feeding can result in defoliation, feeding on new growth after cutting, stunting of plant growth, reduction in yield and quality
Frequent or Occasional Pest	Frequent
Regionality	Through all production regions
Timing of Outbreak	Late winter to early spring, around first cutting

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Beta-cyfluthrin	Baythroid	3A	1.22	Can be disruptive to natural enemies
Spinosad	Entrust (Organic)	5	7.60	Suppression not control; short residual
Phosmet	Imidan	1B	3.03	Shorter residual, can be disruptive to natural enemies
Malathion	Malathion	1B	2.24	Activity is temperature dependent; higher temperatures give greater efficacy
Indoxacarb	Steward	22A	5.32	More selective, no effect on aphids
Lambda - cyhalothrin	Warrior	3A	1.76	Can be disruptive to natural enemies
Zeta-cypermethrin	Mustang	3A	2.81	Can be disruptive to natural enemies

Alternative Management Practices

Practice	Comments
Conservation of natural enemies	Efforts to establish biological control with parasitic wasps have not been effective in most of the range of the weevil in California. Fungal diseases can increase weevil mortality but can be influenced by a lack of rainfall and moisture. General predators have some influence in regulating weevil populations but are insufficient to maintain below damaging levels.
Early cutting	Yield losses and population can be concentrated under windrow and weevils may damage regrowth in these strips. . Early harvest may sacrifice yield and negatively impact economics.
Grazing (sheep)	Mid-winter is best alfalfa is dormant. Sheep are not always available and do not necessarily provide economically viable control. During wet winters, sheep can damage the alfalfa crowns via their tracks/hooves.
Light harrowing during winter	May injure crowns
Burning	Costly, slow and only partially effective; air quality concerns

Other Considerations and Knowledge Gaps

Research	Policy	Education
Refine action threshold Studies to determine if additional weevil generations are occurring New insecticide chemistries aimed at beetles are needed	None Noted	None noted

Blue Alfalfa Aphid

Acyrthosiphon kondoi

A cool weather aphid, blue alfalfa aphid usually appears at the same time or before weevils appear in fields. Populations decline in spring when temperatures begin to exceed 95° F. The aphid prefers plant terminals but at high population densities will spread over the top of the plant.

Since blue alfalfa aphid populations can arise in winter, they develop well before their natural enemies. Thus, their population growth is unimpeded by mortality factors caused by natural enemies during their early appearance.
These aphids feed on alfalfa and inject a toxin that retards growth, reduces yield, and may even kill plants. Damage can also reduce forage quality. A black fungus, sooty mold, grows on the honeydew excreted by the aphid and reduces palatability to livestock. Damage is more severe on short alfalfa than taller plants. The toxin injected by the blue alfalfa aphid is more potent than that of the pea aphid. This toxin has carryover effects and impacts the alfalfa plant/growth for the next one or two cutting cycles even after the blue alfalfa aphid populations had subsided.

Using resistant alfalfa varieties and encouraging populations of natural enemies are very important practices to manage blue alfalfa aphid. Natural enemies, especially lady beetles, should be monitored along with the aphids to determine the need for treatment. Aphids frequently become a problem when their natural enemies are disrupted by weevil sprays. Border harvesting or strip cutting can be important for preserving natural enemies but is rarely done because of the level of management and time required.

Role of Chlorpyrifos: Chlorpyrifos plays an important role in management of this key pest in alfalfa. With no selective insecticides registered on alfalfa, this active ingredient is the primary option, but its efficacy has been inconsistent in recent years. In many cases, weevils and blue alfalfa aphid may be present in a field simultaneously and a significant advantage of chlorpyrifos is that a single application manages both pests.

Pest Status

Attribute	Status
New or Established Pest	Established but has increased in severity the last 2 to 3 years
Potential for Severity/ Economic Loss	Severe potential loss
Damage	Reduction of plant vigor, death of plants at high population densities, reduction in regrowth in the following cutting
Frequent or Occasional Pest	Becoming more frequent
Regionality	Southern deserts valleys, high desert, Central Valley, Intermountain Region
Timing of Outbreak	Late winter (deserts) to early spring (Central Valley) , mid-late spring (Intermountain) before and after first cutting

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Beta-cyfluthrin	Baythroid	3A	0.73	Can be disruptive to natural enemies Not listed in UC IPM PMG for aphids
Dimethoate	Dimethoate	1B	0.74	Reduced efficacy noted, Dimethoate works at cooler temperatures
Lambda - cyhalothrin	Warrior	3A	0.41	Can be disruptive to natural enemies. Not listed in UC IPM PMG for aphids
Methomyl	Lannate	1A	3.17	Broad spectrum, disruptive to natural enemies; Danger, Poison signal word, additional safeguards on label. Not listed in UC IPM PMG for aphids
Malathion	Malathion	1B	1.05	Malathion is regionally effective in the desert where it is hot. Not listed in UC IPM PMG for aphids
Zeta-cypermethrin	Mustang	3A	1.23	Can be disruptive to natural enemies. Not listed in UC IPM PMG for aphids

Alternative Management Practices

Practice	Comments
Resistant varieties	Key management solution but populations have increased on resistant varieties in recent years.
Border cutting	Useful for preserving natural enemies because it helps retain parasitoid larvae and other natural enemies in the field; some loss of yield at that cutting cycle
Conservation of natural enemies	Natural enemies can moderate aphid populations in many fields

Other Considerations and Knowledge Gaps

Research	Policy	Education
There is a need for more IPM compatible insecticide options for aphids. Need higher levels of resistance to aphids in alfalfa plants.	Need more selective aphid materials.	Studies show there is no apparent impact on efficacy from low VOC chlorpyrifos formulations although field reports indicate inconsistent results when used in alfalfa

Cowpea Aphid

Acyrthosiphon craccivora

Cowpea aphid is the most recent arrival in the aphid complex. It appears in high numbers during the summer months but can reach high densities in late winter and early spring. Cowpea aphid injects a powerful toxin into the plant while feeding; and when populations are large, this can stunt or kill plants. While feeding, this aphid produces a considerable amount of honeydew upon which sooty mold grows. The black sooty mold reduces photosynthesis and may make leaves unpalatable to livestock. The honeydew also makes the alfalfa sticky, which causes problems with harvest. Cowpea aphid is a major threat to alfalfa yield during population outbreaks.

Role of Chlorpyrifos: Chlorpyrifos is a very effective insecticide in controlling cowpea aphid. With no selective insecticides registered on alfalfa for aphid management, this active ingredient is the primary option.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Can cause loss to stands, yield and quality
Damage	Stunting to death of plant. Reduction of hay quality due to honeydew deposits.
Frequent or Occasional Pest	Frequent except in Intermountain Region and the Sacramento Valley where it is sporadic pest.
Regionality	Throughout California
Timing of Outbreak	Mostly during summer but also late winter to early spring, in the Central Valley and southern deserts

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Beta-cyfluthrin	Baythroid	3A	0.73	Can be disruptive to natural enemies; not listed in UC IPM PMG
Dimethoate	Dimethoate	1B	0.74	Reduced efficacy noted, dimethoate works at cooler temperatures where chlorpyrifos may not work as well
Lambda - cyhalothrin	Warrior	3A	0.41	Can be disruptive to natural enemies; not listed in UC IPM PMG
Malathion	Malathion	1B	1.05	Malathion is less effective at cooler temperatures
Zeta-cypermethrin	Mustang	3A	1.23	Pest not on label, Can be disruptive to natural enemies

Alternative Management Practices

Practice	Comments
Border cutting	Useful for preserving natural enemies because it helps retain parasitoid and other natural enemies in the field
Conservation of natural enemies	Natural enemies can moderate aphid populations in many fields. Parasitism can be as high as 95% but population densities can be so high as to be enough to cause damage
Early Harvest	Reduced yield

Other Considerations and Knowledge Gaps

Research	Policy	Education
There is a need for more IPM compatible insecticide options for aphids. More effort to develop resistant varieties. Improved aphid sampling protocols	Need a selective aphid material, which is available but not registered in alfalfa, e.g. neonicotinoids which are under scrutiny.	Studies show there is no apparent impact on efficacy from low VOC chlorpyrifos formulations although field reports indicate inconsistent results when used in alfalfa Stem sampling for aphid is not widely used widely used.

Alfalfa Caterpillar
Colias eurytheme

The alfalfa caterpillar is the larva of a butterfly with a distribution throughout most of North America. A native insect, its lifecycle has become adapted to be synchronous with alfalfa production. A warm weather insect, the adult butterfly can be found in swarms in certain years. The larvae feed on alfalfa foliage and can be a problem when the natural enemies fail to control populations to below action thresholds.

Sometimes spraying is recommended when pest population densities are lower than the treatment threshold, if other pests occur in the field that are damaging the alfalfa, or if the infestation occurs when the alfalfa is still short and less tolerant of feeding damage. While alfalfa caterpillar populations are controlled by several products, if allowed to get out of hand, they are difficult to bring back under control.

Alfalfa caterpillars consume entire leaves. The larger larvae are most destructive. In contrast to armyworms, alfalfa caterpillars do not skeletonize leaves and will consume the midrib.

The most important way to control the alfalfa caterpillar is to use selective insecticides in summer and to preserve and encourage its natural enemies by avoiding unnecessary insecticide applications for aphids or weevils in late spring.

Role of Chlorpyrifos: Chlorpyrifos is an effective insecticide against this pest and might be considered when other pests are present.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Outbreaks can be severe in certain years and regions
Damage	Damage to foliage
Frequent or Occasional Pest	Cyclical outbreaks every few years
Regionality	Throughout California
Timing of Outbreak	Summer

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode Of Action Group	Cost Comparison Relative to Lock-On	Comments
Flubendiamide	Belt	28	2.33	Selective, good efficacy
Chlorantraniliprole	Coragen	28	4.35	Selective, good efficacy,
Bacillus thuringiensis	Dipel XenTari	11A	1.00	Reduced control as worms get larger, treat small worms
Methoxyfenozide	Intrepid	18	1.26	Selective
Methomyl	Lannate	1A	1.78	Broad spectrum, Danger Poison signal word, additional safeguards
Indoxacarb	Steward	22A	2.10	Selective

Alternative Management Practices

Practice	Comments
Border cutting	Useful for preserving the natural enemies because it helps retain parasitoids and other natural enemies in the field; some loss of yield at that cutting cycle.
Early cutting	Early harvesting of fields infested with economic levels of alfalfa caterpillars kills larvae. Yield may be reduced.
Conservation of natural enemies	Parasitic wasps (*Cotesia medicaginis*) are critical to population management; look for parasitoids in caterpillars when monitoring.

Other Considerations and Knowledge Gaps

Research	Policy	Education
Improved sampling protocols, e.g. using egg monitoring	None noted	Worms are not being inspected for parasitism

Armyworms - Beet and Yellow-striped

Spodoptera exigua and S. praefica

Armyworms are common pests in the Central Valley and desert valleys from June through September. There are at least 5 generations per year in the low desert and three or four in the Central Valley. The final generation may overwinter as large larvae or pupae. The Crop Team reports that this is the most difficult of the worm complex to control and populations remain in the field longer, threatening multiple cuttings. Eggs are deposited in masses and covered by the moth's scales.

Armyworms skeletonize foliage, leaving veins largely intact. First and second instar larvae tend to feed in clusters around the egg mass from which they hatch. This whitish appearance caused by the feeding is known as "whitecaps" and is very visible across a field. This frequently causes a tattered appearance to the terminals.

Populations of armyworms are frequently controlled by natural enemies and are more or less cyclic, only occurring in large numbers every few years. Early harvest, border cutting, and biological control are important components of a management program that can prevent damage from armyworms.

Role of Chlorpyrifos: Chlorpyrifos has been used widely for the control of this pest. While still useful, this active ingredient has been reported to be losing effectiveness in some growing areas.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	High potential for damage
Damage	Armyworms skeletonize leaves,
Regionality	Throughout California production areas
Frequent or Occasional	Cyclical outbreaks every few years
Timing of Outbreak	Summer

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lock-On	Comments
Flubendiamide	Belt	28	2.04	Selective, good efficacy
Chlorantraniliprole	Coragen	28	3.57	Selective, good efficacy
Methoxyfenozide	Intrepid	18	1.10	Selective
Methomyl	Lannate	1A	1.56	Broad spectrum, Danger Poison signal word, additional safeguards
Indoxacarb	Steward	22A	1.84	Selective, good efficacy, used against weevils
Bacillus thuringiensis	Xentari, Agree	11 A	1.46	Reduced control as worms get larger, treat small worms

Alternative Management Practices

Practice	Comments
Border cutting	Useful for preserving the natural enemies because it helps retain parasitoid and other natural enemies in the field; some loss of yield at that cutting cycle.
Conserve natural enemies	Natural enemies can provide good control of armyworms in many fields.
Timing of cutting	Early harvesting of fields infested with economic levels of beet and western yellow-striped armyworms kills larvae. Yields may be reduced.

Other Considerations and Knowledge Gaps

Research	Policy	Education
Improved sampling designs Revisit action threshold levels	None noted	Worms are not being inspected for parasitism.

Pea Aphid

Acrythosiphon pisum

The pea aphid prefers cool temperatures and reaches damaging levels in the spring and may be present in alfalfa fields at the same time as alfalfa weevils. Pea aphid often reoccurs in fall as well. The pea aphid is usually more generally distributed in the plant but prefers the stems to the leaves.

These aphids feed on alfalfa and inject a toxin that retards growth and reduces yield. Damage can also reduce alfalfa's feed value. A black fungus, sooty mold, grows on the honeydew excreted by the aphid reducing palatability to livestock. Damage is more severe on short plants than on taller alfalfa. The toxin injected by the pea aphid is less potent than that injected by the blue alfalfa aphid.

Role of Chlorpyrifos: Chlorpyrifos plays an important role in management of this pest. With no selective insecticides registered on alfalfa for aphids, this active ingredient is the primary option and has performed well in reducing pea aphid populations. In many cases, weevil and blue alfalfa aphid may also be present in a field and single application of chlorpyrifos can reduce populations of all three pests.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Potential for severe damage
Damage	Stunting of plants, production of honeydew which allows sooty mold to develop and reduces quality and value of hay
Frequent or Occasional Pest	Frequent
Regionality	Throughout all production regions in California
Timing of Outbreak	Spring and occasionally in fall

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Beta-cyfluthrin	Baythroid	3A	0.73	Can be disruptive to natural enemies; Not listed in UC IPM PMG
Dimethoate	Dimethoate	1B	0.74	Reduced efficacy noted, dimethoate works at cooler temperatures where chlorpyrifos may not work as well
Malathion	Malathion	1B	1.05	Less effective at lower temperatures
Zeta-cypermethrin	Mustang	3A	1.23	Can be disruptive to natural enemies; Not listed in UC IPM PMG
Lambda - cyhalothrin	Warrior	3A	0.41	Can be disruptive to natural enemies; Not listed in UC IPM PMG

Alternative Management Practices

Practice	Comments
Resistant varieties	Key management solution but populations have increased on resistant varieties in recent years.
Border cutting	Useful for preserving the natural enemies because it helps retain parasite larvae and predators in the field; some loss of yield at that cutting cycle.
Conservation of natural enemies	Natural enemies can moderate aphid populations in many fields.

Other Considerations and Knowledge Gaps

Research	Policy	Education
There is a need for more IPM compatible insecticide options for aphids. Need for alfalfa varieties with increased levels of resistance.	Over reliance on two OP products for treating aphids: chlorpyrifos and dimethoate, additional registrations of selective AIs are needed.	Studies show low VOC chlorpyrifos formulations are effective although field reports indicate inconsistent results when used in alfalfa Stem sampling is not widely used. Stem sampling is not widely used.

Cutworms – Variegated and Granulate

Peridroma saucia and Agrotis subterranea

Cutworms are primarily night feeding pests and hide under loose soil, in soil cracks, or under duff during the day. Variegated cutworm populations may develop in weedy areas and migrate into seedling stands or occasionally mature stands. Injurious populations usually occur from April to late June. Seedling alfalfa stands can be severely damaged by cutworms cutting the seedlings off at or just below the soil surface. Established fields are damaged when cutworms cut off new growth or feed on the alfalfa foliage and roots causing entry wounds for secondary pathogens.

Granulate cutworm is a devastating pest of bed-planted alfalfa and can also be a pest of alfalfa planted between borders. Low Desert alfalfa fields are attacked from May through October. Established alfalfa fields can be severely injured when cutworms cut off new shoots at or below ground level following harvest. This pest often goes undetected after cutting and hay removal, but the problem becomes apparent when the field is irrigated and there is little or no regrowth.

Role of Chlorpyrifos: Chlorpyrifos is not regularly used to control this pest.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Potential for severe damage
Damage	Stunting of plants, production of honeydew which allows sooty mold to develop and reduces quality and value of hay
Frequent or Occasional Pest	Frequent
Regionality	Throughout all production regions in California
Timing of Outbreak	Spring and occasionally in fall

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Beta-cyfluthrin	Baythroid	3A	0.31	Can be disruptive to natural enemies
Flubendiamide	Belt	28	3.89	Selective, good efficacy Not listed in UC IPM PMG
Permethrin	Pounce	3A	0.64	Can be disruptive to natural enemies
Indoxacarb	Steward	22A	2.50	Selective
Lambda - cyhalothrin	Warrior	3A	0.66	Can be disruptive to natural enemies

Alternative Management Practices

Practice	Comments
Water Management	Flood irrigation – less likely to be employed in water short environment
Management of weeds	Keep the field and field edges weed-free
Conserve natural enemies	Parasitism can be as high as 95% but population densities can be high enough to cause damage
Plant alfalfa into well prepared fields	Avoid planting into fields with undecomposed organic matter

Other Considerations and Knowledge Gaps: None noted.

Leafhoppers

Southern garden leafhopper: *Empoasca solana*
Potato leafhopper: *E. fabae*
Mexican leafhopper: *E. mexara*

A complex of leafhoppers are present in California alfalfa fields and are collectively referred to as *Empoasca* leafhoppers. They all have the same general appearance and cause similar damage. Infestations frequently begin at field margin and often infestations are contained to the first 50-100 feet of the field margin. In addition, the three cornered alfalfa hopper is also becoming more of a pest in some areas where it may reduce yields by girdling alfalfa stems at the base of the plant.

The most common damage symptom of Empoasca leafhoppers is a yellow, wedge-shaped area at the tip of the leaf. Frequently, the leaf margin and tissue surrounding this area turns red. Plants may become stunted and have very short internodes. Stunting and yellowing may persist into the next cutting cycle, even in the absence of leafhoppers.

Although Empoasca leafhoppers may be found throughout the year, damage in the Central Valley is generally found during July, August, and occasionally September. In the Imperial Valley, damage may occur from May through October; infestations are often adjacent to or upwind from sugarbeets.

If border strips are utilized to preserve natural enemies, leafhopper populations can build to damaging levels in these strips.

Role of Chlorpyrifos: Chlorpyrifos is effective in controlling these pests. If multiple pests are present, chlorpyrifos is a preferred choice because of its efficacy on a range of pests.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate threat to yield and quality
Damage	Stunting, shortened internodes and yellowing of plants
Frequent or Occasional Pest	Occasional
Regionality	Throughout California, except intermountain region
Timing of Outbreak	Summer

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Permethrin	Ambush, Pounce	3A	1.55	Can be disruptive to natural enemies
Beta-cyfluthrin	Baythroid	3A	0.62	Can be disruptive to natural enemies
Dimethoate	Dimethoate	1B	0.99	10 day PHI
Phosmet	Imidan	1B	2.85	Can be disruptive to natural enemies
Methomyl	Lannate	1A	NA	Pest not on label
Malathion	Malathion	1B	2.10	Temperature sensitive
Zeta-cypermethrin	Mustang	3A	2.64	Can be disruptive to natural enemies
Carbaryl	Sevin	1A	2.91	7 day PHI Can be disruptive to natural enemies
Lambda - cyhalothrin	Warrior	3A	1.32	Can be disruptive to natural enemies

Alternative Management Practices

Practice	Comments
Timing of cutting	If alfalfa is within a few days of harvest, early cutting will control *Empoasca* leafhoppers.

Other Considerations and Knowledge Gaps: None noted.

Spotted Alfalfa Aphid

Therioaphis maculata

This aphid prefers warm weather and is generally found during summer months. In the Imperial Valley, high populations may continue into fall and winter. Spotted alfalfa aphids inject a toxin into the plant as they feed. Severe aphid infestations stunt plants, reduce yield, and may even kill plants. These aphids also secrete large quantities of honeydew. Plants become very sticky at relatively low aphid densities, and a black fungus that grows on the honeydew excreted by the aphid reduces palatability to livestock and lowers the alfalfa's feed value.

Resistant varieties have been a major factor in managing this pest for decades and insecticide treatment is rarely needed.

Role of Chlorpyrifos: Chlorpyrifos is not widely used against this pest.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Severe
Damage	Severe aphid infestations stunt plants, reduce yield, and may even kill plants. They secrete large quantities of honeydew resulting in plants becoming very sticky at relatively low aphid densities
Frequent or Occasional Pest	Occasional
Regionality	Southern desert valleys, SJV
Extent of Outbreak	Aphid is widespread in fields, but outbreak prevented by varietal selection
Timing of Outbreak	Summer

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Beta-cyfluthrin	Baythroid	3A	0.73	Can be disruptive to natural enemies Not listed in UC IPM PMG
Dimethoate	Dimethoate	1B	0.74	Reduced efficacy noted, dimethoate works at cooler temperatures
Lambda - cyhalothrin	Warrior	3A	0.41	Can be disruptive to natural enemies Not listed in UC IPM PMG
Malathion	Malathion	1B	1.05	Less effective at lower temperatures Not listed in UC IPM PMG
Zeta-cypermethrin	Mustang	3A	1.23	Can be disruptive to natural enemies Not listed in UC IPM PMG

Alternative Management Practices

Practice	Comments
Resistant varieties	Most effective and durable approach to controlling aphids in alfalfa.
Conservation of natural enemies	Natural enemies can moderate aphid populations in many fields.
Border cutting	Useful for preserving the natural enemies because it helps retain parasitoids and predators in the field; some loss of yield at that cutting cycle.

Other Considerations and Knowledge Gaps

Research	Policy	Education
We need more IPM compatible options for aphids. Increased aphid resistance in alfalfa varieties.	Need registration for more selective aphid materials.	Studies show there is no apparent impact on efficacy from low VOC chlorpyrifos formulations although field reports indicate inconsistent results when used in alfalfa Stem sampling for aphids is not widely used.

Webworm

Loxostege cereralis

Several species may infest alfalfa but alfalfa webworm is the most commonly encountered. Webworms overwinter as larvae in the ground adjacent to their fall food host. Moths emerge in early spring and lay eggs on leaves of host plants. Larvae will feed for 3 to 5 weeks. The larval stage feeds inside of webbed leaves on the upper parts of the plant in summer and fall. If numbers are abundant, this webbing will be clearly visible and will cover extensive areas of foliage. Treatment is rarely justified in California.

Role of Chlorpyrifos: Chlorpyrifos is a primary active ingredient in managing this pest. Limited efficacy information is available on other active ingredients.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Minor
Damage	Web over leaves, feed on foliage
Frequent or Occasional Pest	Occasional
Regionality	Reported in High Desert as pest of concern
Timing of Outbreak	Summer

Alternative Active Ingredients (AI) – UC IPM PMG does not have any products listed

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Bacillus thuringiensis	Xentari, Agree	11A	1.46	Reduced control as worms get larger, treat small worms
Permethrin	Ambush, Pounce	3A	0.64	Can be disruptive to natural enemies
Beta-cyfluthrin	Baythroid	3A	0.57	Can be disruptive to natural enemies
Flubendiamide	Belt	28	2.78	Selective
Methoxyfenozide	Intrepid	18	1.50	Selective
Carbaryl	Sevin	1A	0.91	Can be disruptive to natural enemies
Lambda - cyhalothrin	Warrior	3A	0.33	Can be disruptive to natural enemies
Zeta-cypermethrin	Mustang	3A	0.88	Can be disruptive to natural enemies

Alternative Management Practices

Practice	Comments
Timing of cutting	Early cutting may give satisfactory control, though yields may be reduced.

Other Considerations and Knowledge Gaps

Research	Policy	Education
Thresholds need to be established Cultural and biological practices need to be developed	None Noted	Pest management guidelines require further development

Almond Crop Team Report

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Overview

The Almond Crop Team identified a total of 12 insect pests for which chlorpyrifos is considered extremely important to the industry's pest management program. Of these, leaffooted bugs and stink bugs emerged as pests against which there are no suitable alternatives to chlorpyrifos. Chlorpyrifos will remain an important pest management tool in almonds until new, effective controls are registered or other management tactics developed. The Crop Team noted the importance of this active ingredient in managing leaffooted bugs and stink bugs does not diminish the need to control other identified pests in season and during dormancy.

Introduction and Background

Almonds are California's top export crop and the largest single United States specialty crop exported. For the 2013-2014 crop year, California produced $5.85 billion farm gate of almonds on 860,000 bearing acres of orchards. There are currently an additional 100,000 acres of non-bearing orchards due to come into full production in the next 3-5 years. Since over 80% of the crop is exported, it is critically important that nuts meet all international food safety standards, including MRLs established by importing countries.

The Almond Crop Team identified two major regions of almond production in California, the San Joaquin Valley and the Sacramento Valley (Figure 3.1), based on insect pest complexes (Figure 3.2) and environmental conditions.

• *San Joaquin Valley: There is high pressure from navel orangeworm (NOW), web spinning mites, leaffooted bug, the stink bug complex and ants. Peach twig borer, San Jose scale, and others are common concerns of growers.*

• *Sacramento Valley: There is less pressure from NOW and webspinning spider mites, leaffooted bug, the stink bug complex and ants. However, peach twig borer and oriental fruit moth are of greater importance than in the San Joaquin Valley.*

Almond Integrated Pest Management (IPM)

The Almond Board of California has funded pest management research since 1973 in order to provide almond growers with science-based, IPM solutions for many pest problems.

Figure 3.1. Almond production areas in California

Almond Production in California
- 860,000 bearing acres
- 5.85 Billion dollars
- 2,393 kernel pounds/acre

The major efforts of the Almond Board in the 1980s and 1990s were improved sampling, decision making, and alternative management practices to broad spectrum insecticides.

Almond IPM programs have been, in part supported by California Department of Pesticide Regulation Pest Management Alliance (PMA) grants to reduce organophosphate insecticide use. Industry supported research has resulted in the reduction of organophosphates during winter dormancy and as well as high levels of adoption of IPM practices.[1,2]

[1] *Epstein, L, S. Bassein, F.G. Zalom 2000.Almond and stone fruit growers reduce OP, increase pyrethroid use in dormant sprays. California Agricutlure. November-December pp14-19.*

[2] *Brodt, Sonja, Frank Zalom, Rose Krebill-Prather, Walt Bentley, Carolyn Pickel, Joseph Connell, Larry Wilhoit, Marcia Gibbs. 2005. Almond growers rely on pest control advisers for integrated pest management. California Agriculture. October-December 2005. pp. 242-248.*

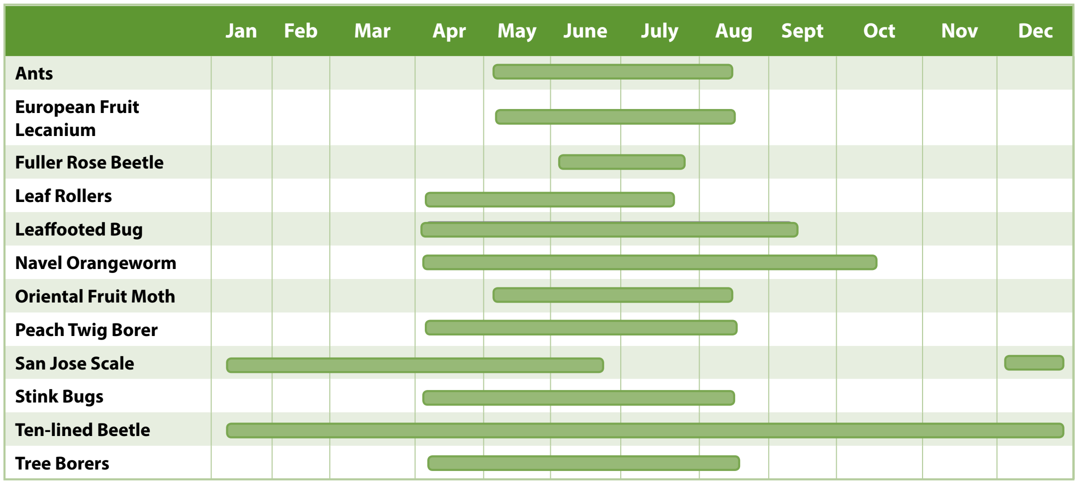

Figure 3.2. Seasonality of almond pests. If the average cost per acre is equal to the price of chlorpyrifos, the value would be 1.0.

Criticality of Chlorpyrifos in Almond IPM

Chlorpyrifos is one of many active ingredients used by growers and PCAs in almond pest management. (Appendix 4) During the process of identifying critical uses, 12 insect pests were identified (Table 3.1). Of these, 2 were considered **Key** with few or no alternative products, six were considered **Important** but alternative active ingredients were available, and four were considered **Occasional** pests with alternative active ingredients available. It is important to note that while leaffooted bugs and stink bugs were listed as pests against which chlorpyrifos was critical, this does not diminish the importance of the role chlorpyrifos plays in controlling the other identified pests throughout the entire year. Details are provided for each pest in the Pest Profiles section.

Critical Uses of Chlorpyrifos in Almonds

Criticality Tier	Pest	Number of Modes of Action in Addition to Chlorpyrifos	Alternative Practices Available
Key Pests with Few or No Effective Alternatives	Leaffooted Bug	3	No
	Stink Bugs	3	Yes
Important Pests with Alternatives	Ants – Protein feeding	6	No
	European Fruit Lecanium	2	Limited
	Navel Orangeworm	8	Yes
	Oriental Fruit Moth	6	Yes
	Peach Twig Borer	8	No
	San Jose Scale	4	No
Occasional Pests with Alternatives	Tree Borers (Prune Limb, American Plum)	2	Limited
	Ten-lined Beetle	Unknown	No
	Fuller Rose Beetle	1	No
	Leafroller	6	No

Table 3.1. Critical uses of chlorpyrifos in alfalfa. Modes of action refer to the Insecticide Resistance Action Committee (IRAC) classification (www.irac-online.org).

Chlorpyrifos Use Pattern

According to data from CDPR Pesticide Use Reports during the period 2002-2012, total pounds of chlorpyrifos use peaked in 2006 and have decreased to about 200,000 lbs per year between 2007 and 2012 (Figure 3.3). The pounds of active ingredient per treated acre generally held steady at an average of 1.86 lbs during the period from 2002 to 2012 (Appendix 9).

The most critical need for chlorpyrifos is for leaffooted bug and bug complex sprays, primarily from May – July (Figure 3.4). Alternatives to chlorpyrifos are currently being field tested, but the data strongly suggests that these products have virtually no residual activity. Secondarily, chlorpyrifos is a "back-up" insecticide in dormant sprays in the event resistance to pyrethroid insecticides develops. Chlorpyrifos is also used at hull split in the July – August timing. It is thought fuming action may aid in control of already hatched NOW larvae that

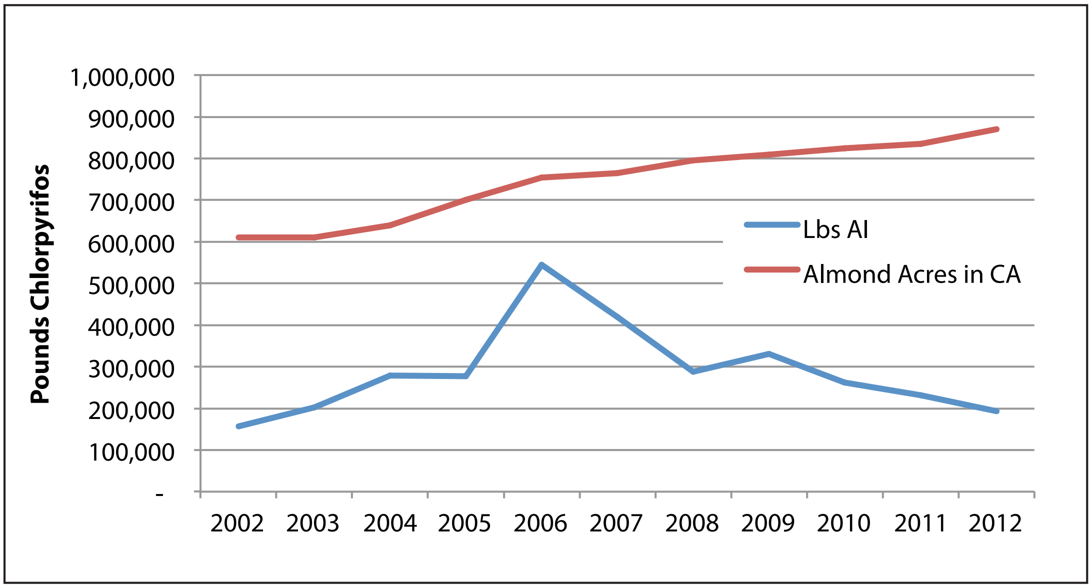

Figure 3.3. Chlorpyrifos use and almond acreage (2002-2012).
(Source: CDPR PUR & CASS)

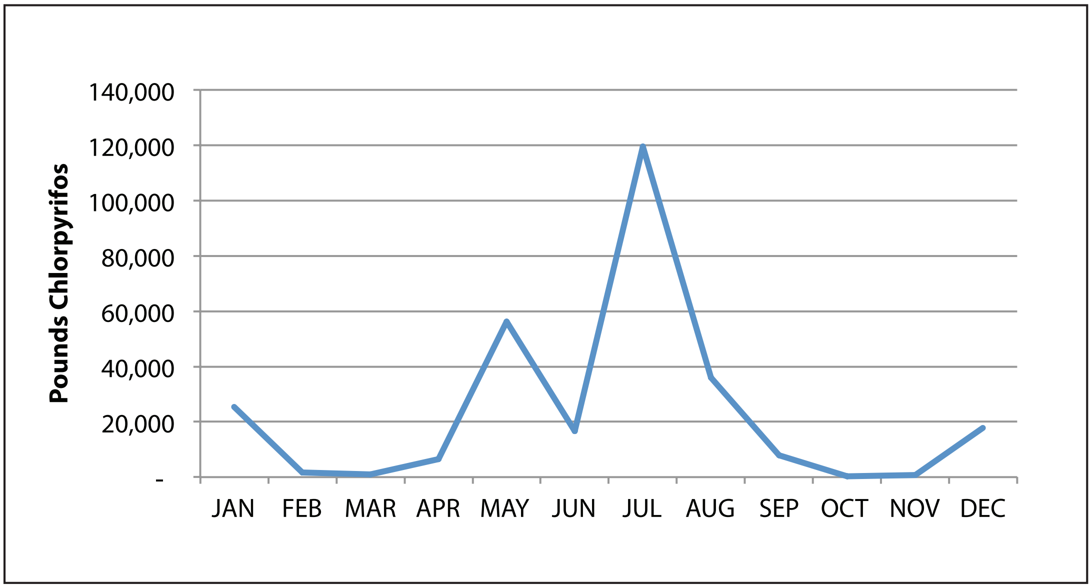

Figure 3.4. Monthly use of chlorpyrifos in almonds (2002-2012).
(Source: CDPR PUR)

have entered into the hull or kernel; however, fuming action has not been researched and has not been documented. However, chlorpyrifos is critical in some situations to initiate a mating disruption based program for NOW. An initial high use period serves to depress NOW populations to levels amenable for effectively implementing mating disruption. This typically leads to large reductions in pesticide use after the initial period.

The Crop Team emphasized the importance of chlorpyrifos in managing all of these identified pests in almonds. They also pointed out the need to have MRLs established for all pesticides given the importance of international trade of their commodity.

Cost of Alternative Active Ingredients

The cost of alternative active ingredients relative to chlorpyrifos depended on cost per unit of product and the recommended rates per acre. Table 3.2 presents the relative costs of alternative AIs to chlorpyrifos for control of alfalfa pests. The range of relative costs varied between a low 0.16 the cost of chlorpyrifos to a high of 4.45. Details of alternative active ingredients can be viewed individually in the Pest Profiles section.

Leaffooted bugs and stink bugs tend to be the drivers of chlorpyrifos use. Years with high pressure from these pests results in much higher use (e.g. 2006 in Figure 3.4).

Tier	Pest	Low	High	Comments
1	Leaffooted Bug	0.61	1.21	Very effective and economical
	Stink Bug	0.16	1.21	Highly effective; populations can build up after bio based program
2	Ants, Protein Feeding	0.38	0.77	Baits effective; need as option close to harvest
	European Fruit Lecanium	NA	NA	Not labeled for use
	Navel Orangeworm	0.20	3.21	Supports mating disruption (MD), effective at critical time, NOW creates food safety and trade issues
	Oriental Fruit Moth	1.01	2.47	Occasional use, helps with multiple pests
	Peach Twig Borer	1.19	4.16	Dormant, delayed dormant or post bloom
	San Jose Scale	1.74	4.45	Dormant treatment with oil
3	Leaf Roller	NA	NA	Not labeled for use
	Fuller Rose Beetle	NA	NA	Not labeled for use
	Ten-Lined Beetle	NA	NA	Not labeled for use
	Tree borers	NA	NA	Not labeled for use
	Summary	**0.16**	**4.45**	

Table 3.2. Relative costs of alternative AIs compared to chlorpyrifos products in almonds. If the average cost per acre is equal to the price of chlorpyrifos, the value would be 1.0.

Gaps in Research, Extension and Policy

The Almond Crop Team identified major research, extension and policy issues impacting their commodity. The following are general and listed in no specific order of priority. See each Pest Profile for specific needs expressed during the discussions.

Research

The Almond Crop Team agreed that research on leaffooted bug, stink bug, hull split and dormant sprays would provide the most benefits in terms of addressing any concerns related to chlorpyrifos use. In addition, NOW is a very high priority pest since it is a major pest which presents food safety and trade issues for almonds.

- *Analyze CDPR PUR data to identify pest and area specific chlorpyrifos use*
- *Evaluate efficacy of clothianidin (Belay) for leaffooted bug and stink bug complex*
- *Evaluate new low VOC formulations of chlorpyrifos*
- *Develop efficacy data for new compounds*
- *Determine the best technical fit for new AI's in almond IPM*
- *Evaluate impacts of new products on pollinators*
- *Develop predictive models for leaffooted and stink bug population dynamics*
- *Develop improved understanding of leaffooted bug and stink bug biology for better monitoring (early warning and in-orchard systems)*
- *Develop reliable economic thresholds for leaffooted bugs and stink bug complex*
- *Evaluate regional disparity of application methodology for NOW control*
- *Conduct studies on hull-split timing to increase efficacy and reduce inputs*
- *Develop reliable and efficient monitoring techniques for ants*
- *Research application timing and equipment to increase efficacy*
- *Research application timing and equipment to reduce off site movement of pesticides*
- *Develop improved understanding of plant development and physiology as it relates to vulnerability/tolerance to pests*

Extension

Outreach through extension will continue to be critical, but there are major concerns about manpower needs for training PCAs and growers about new products and techniques. California needs to reinvest in entomology, including more knowledge development and dissemination through UC Cooperative Extension Farm Advisors and research scientists. Extension staff has been reduced in capacity even though the almond acreage is increasing.

- *Provide pest management training to new PCAs and consultants*
- *Increase utilization of monitoring programs for San Jose scale*
- *Improve pest identification resources and guidelines*
- *Provide adoption support for mating disruption via large scale demonstrations in multiple areas*
- *Demonstrate the best technical fit for new AI's in almond IPM*

Policy Needs

Pesticide use information should be used to guide research and outreach activities. Due to the importance of international trade to the almond industry, regulatory harmonization and expedited MRLs are of utmost importance.

• Utilize CDPR PUR data to prioritize and regional research and outreach related to chlorpyrifos use

• Evaluate the impact of VOC regulations on chlorpyrifos use patterns

• Consider the role of generic chlorpyrifos availability in use patterns

• Consider the role of generic chlorpyrifos availability in proposed regulations

• Encourage US EPA and USDA to continue MRL harmonization activities with other international regulatory authorities to streamline the process

• Communicate with registrants about long term pest management needs and registration priorities for new chemistries and MRLs

Potential Funding Sources for Almond IPM

The Almond Crop Team identified potential sources of funding to support research and outreach projects related to chlorpyrifos use in IPM systems.

Source	Organization and/or Program
Commodity	Almond Board of California
State	California Department of Food and Agriculture Specialty Crop Block Grant Program CA Department of Pesticide Regulation - Research Grants and Pest Management Alliance Grants
Federal	EPA IR-4 Minor Use Registration Program USDA-FAS Technical Assistance to Specialty Crops (TASC) USDA Crop Protection and Pest Management (CPPM) USDA Natural Resources Conservation Service (NRCS) USDA Pest Management Alternatives (PMAP) USDA Integrated Organic Program (IOM) USDA National Extension Integrated Pest Management Projects Program (EIPM) USDA Sustainable Agriculture Research and Education (SARE) USDA Specialty Crop Research Initiative (SCRI)
Regional	Western Region IPM Center - Work Groups and Pest Management Strategic Plans
Corporate	Pesticide manufacturers Farming organizations

Best Management Practices to Mitigate Use of Chlorpyrifos in Almonds

When planning for possible chlorpyrifos applications in an IPM program, consult the UC IPM Guidelines and consider the following Best Management Practices. For additional information, refer to the "Resources" section at the end of this document.

Consider water management practices that reduce pesticide movement off-site:

- ☐ Manage water use amount using soil moisture and evapotranspiration (ET) monitoring.
- ☐ Install an irrigation recirculation or storage and reuse system.
- ☐ Use drip rather than sprinkler or flood irrigation.
- ☐ Consider the use of cover crops.
- ☐ Consider vegetative filter strips or ditches.
- ☐ Install sediment traps.
- ☐ Use polyacrylamide in furrow irrigation systems to prevent off-site movement of sediments.
- ☐ Apply polyacrylamides in sprinkler irrigation systems to prevent runoff.
- ☐ Redesign inlets and outlets into tailwater ditches to reduce erosion.

Consider management practices that reduce air quality problems.

- ☐ When possible, reduce volatile organic compound (VOC) emissions by decreasing the amount of pesticide applied, choosing low-emission management methods, and avoiding emulsifiable concentrate (EC) formulations.
- ☐ Use the CDPR calculators to determine VOC emission rates from fumigant and non-fumigant pesticides.

Choose a pesticide from the UC IPM Almond PMG for the target pest, considering:

- ☐ Impact on natural enemies and honey bees.
- ☐ Potential for water quality problems using the UC IPM WaterTox database.
- ☐ Impact on aquatic invertebrates.
- ☐ Chemical mode of action (based on efficacy, spectrum of activity, and pesticide resistance). Select an alternative chemical or nonchemical treatment when resistance risk is high.

Before an application:

- ☐ Ensure that spray equipment is properly calibrated to deliver the desired pesticide amounts for optimal coverage.
- ☐ Minimize off-site movement of pesticides.
- ☐ Use appropriate spray nozzles and pressure.
- ☐ Avoid spraying during conditions conducive to drift or runoff.
- ☐ Identify and take special care to protect sensitive areas surrounding the 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:

- ☐ Record application date, product used, rate, and location of application.
- ☐ Follow up to confirm that treatment was effective.

For more information, see UC IPM's Mitigating Pesticide Hazards (http://www.ipm.ucdavis.edu/mitigation/index.html)

Pest Profiles

As a part of the critical use discussions, the Almond Crop Team identified a list of important pests for which chlorpyrifos is considered an important pest management tool.

In order to characterize these pests, general information on the role of this product in IPM, damage, seasonality, frequency and severity of pest outbreaks has been summarized for each species. In addition, information on cost and effectiveness of alternative products and management practices for each pest were assembled in order to have a basis for evaluation and comparison.

This information has been presented in a standardized format simply to describe the role of chlorpyrifos in IPM for the purpose of this project. For detailed information on pest biology, damage and pesticide usage, the UC IPM Pest Management Guidelines for almond production and CDPR Pesticide Use Report are recommended.

The following section presents pests identified by the Almond Crop Team. The pests are presented in order of the criticality ranking determined by the team.

Leaffooted Bug

Leptoglossus phyllopusarium

The leaffooted bug is a sporadic pest in almonds that can cause significant damage, especially in the lower San Joaquin Valley. The leaffooted bug overwinters in the adult stage in aggregations outside of orchards, or near orchards on several native host plants, from which it migrates into orchards in March or early April in search of nuts on which to feed. Feeding by adult leaffooted bugs on young nuts before the shell hardens can cause the embryo to wither and abort and nuts drop from the tree or gum internally, resulting in a bump or gumming on the kernel. After the shell hardens, leaffooted bug feeding can possibly cause black spots on the kernel or wrinkled, misshapen nutmeats. Some varieties are more susceptible to leaffooted bugs than others.

Role of Chlorpyrifos: Chlorpyrifos has been the standard and economical option for control of leaffootted bugs in IPM programs. New pyrethroids are effective, but these products may flare mites and there are concerns about potential resistance.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate to severe
Damage	Direct damage to kernels or abortion of nuts
Frequent or Occasional Pest	Occasional outbreaks but consistent low level damage
Regionality	Lower SJV impacted more
Timing of Outbreaks	April – May when nuts abort, June-July necrotic spots

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Bifenthrin	Brigade	3A	1.35	More broad spectrum. There are generics available that are much less expensive.
Clothianidin	Belay	4A	2.96	Based on Lygus rate - leaf footed NOT on label
Esfenvalerate	Asana	3A	0.16	More broad spectrum
Lambda - cyhalothrin	Warrior	3A	0.19	More broad spectrum
Chlorpyrifos	Lorsban	1B	1.00	None noted

Alternative Management Practices: None noted

Other Considerations and Knowledge Gaps

Research	Policy	Education
Efficacy data for clothianidin (Belay) Need new chemistries evaluated Prediction techniques/ models Monitoring techniques	MRLs need to be established for all pesticides used for this pest.	Need demonstration and outreach for clothianidin Use of pyrethroids may flare mites

Stink Bugs

Green plant bug: *Chlorochroa uhleri*
Green stink bug: *Acrosternum hilare*
Redshouldered stink bug: *Thyanta pallidovirens*
Consperse stink bug: *Euschistus conspersus*

Stink bugs often develop in weeds or field crops and migrate into almonds during spring, as weed or crop hosts dry up. The exception is the green stink bug which overwinters within the orchard.

Stink bug damage to almonds is usually caused by the green stink bug. For decades this bug never reached pest status because broad-spectrum dormant insecticide treatments prevented it from overwintering in almonds. More recently there have been increasing reports of stink bug damage, especially in the lower San Joaquin Valley, in orchards where organophosphate, carbamate, or pyrethroid insecticides have not been used for 3 to 4 years.

Damage by stink bugs usually occurs from May through July, when the bugs insert their straw-like mouthparts through the hull and into the kernel. Kernels of damaged nuts either become wrinkled and misshapen, or if already hardened before bug damage will contain a black spot at the puncture site.

Role of Chlorpyrifos: Highly effective industry standard for treatments. Stink bugs build up over time; treatments are usually needed every 1-2 years. These may arise in orchards that have previously had a biologically-based IPM program. Unfortunately, there are no real alternatives that do not flare mites.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate - Severe
Damage	Misshapen or discolored kernels
Frequent or Occasional Pest	Occasional to Frequent
Regionality	Lower San Joaquin Valley
Timing of Outbreaks	Mid-season (May – June)

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Bifenthrin	Brigade	3A	1.35	More broad spectrum; generic formulations economical
Clothianidin	Belay	4A	0.79	Based on Lygus rate - SBs not on label ;not effective
Esfenvalerate	Asana	3A	0.16	More broad spectrum
Lambda - cyhalothrin	Warrior	3A	0.19	More broad spectrum
Chlorpyrifos	Lorsban	1B	1.00	None noted

Alternative Management Practices: None noted

Other Considerations and Knowledge Gaps

Research	Policy	Education
Efficacy data for clothianidin Need new chemistries evaluated Prediction techniques/ models	MRLs need to be established for all pesticides used for this pest.	None noted

Ants – protein feeding

Pavement ant: ***Tetramorium caespitum***
Southern fire ant: ***Solenopsis xyloni, S. molesta (predominant ant species in almond orchards)***

The southern fire ant has a wider distribution and generally causes more damage than the pavement ant. Ants are more prevalent in drip- or sprinkler-irrigated orchards than flood-irrigated orchards. Ants feed on other hosts and are principally a problem after almonds are on the ground; nut damage increases in relation to the length of time they are on the ground.

Ants can completely hollow out nutmeats leaving only the pellicle. Damage potential of ants appears to be less in weed-free orchards and those without cover crops. Damage is also lower on varieties that have nuts with tight shell seals. Shell seal can vary greatly from year to year depending on variety, crop size, and horticultural practices. Heavy crops that result in small nuts will likely have less open shells and thus less potential for ant damage.

Role of Chlorpyrifos: Baits are the primary method for controlling protein-feeding ants in almonds. However, they take a long time to work (typically 6-8 weeks). In cases where baiting programs fail and supplemental ant control is needed within a few weeks prior to harvest, chlorpyrifos can be applied. There is a need to keep chlorpyrifos as an option close to harvest. Ants have become more of a problem as micro-irrigation methods have become more widely used, replacing flood irrigation. The ant situation in almonds is a good example of due diligence in pest management to find replacement products; the alternatives to chlorpyrifos have become the standard.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate to severe
Damage	Ants can completely hollow out nutmeats
Frequent or Occasional Pest	Damage occurs every year
Regionality	Widespread in the state and especially associated with drip and microsprinklers
Timing of Outbreak	Only an issue at harvest when nuts are on the ground

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Abamectin	Clinch	6	0.49	Bait
Boric Acitd	Boric Acid	UC	0.77	
Metaflumizone	Altrevin	22	0.46	Bait
Methoprene	Extinguish	7A	0.38	Bait
Pyriproxyfen	Esteem Ant Bait	7C	0.47	
Spinosad	Seduce Ant Bait	5	NA	Bait. Current label allows use in almonds against ants (except fire ants). Manufacturer plans on adding fire ants to the label if efficacy data can be obtained. OMRI Certified.
Chlorpyrifos	Lorsban	1B	1.00	None noted

Alternative Management Practices

Practice	Comments
Prompt nut removal from the ground	None noted

Other Considerations and Knowledge Gaps

Research	Policy	Education
Short-term efficacy data for baits that have potential to work quickly metaflumizone (Altrevin) and spinosad (Seduce) Need more long-term efficacy data for: Ababmectin (Clinch) Pyriproxyfen (Esteem) Methoprene (Extinguish) metaflumizone (Altrevin) Improve monitoring techniques	MRLs need to be established for all pesticides used for this pest.	Demonstration for: Ababmectin (Clinch) Pyriproxyfen (Esteem) Methoprene (Extinguish) metaflumizone (Altrevin) Proper use of ant baits

European Fruit Lecanium

Parthenolecanium corni

European fruit lecanium occurs throughout the Central Valley and has increased in severity as growers reduce dormant sprays. Eggs are laid in spring and hatch from May to July. The chief injury is the production of honeydew that, in large amounts, can damage leaves and fruit. Sooty mold growing in the honeydew can cause blackened areas on leaves and fruit. Natural enemies frequently keep lecanium scale below damaging populations. If treatment is needed, oil during dormancy or delayed dormancy is the best treatment.

Role of Chlorpyrifos: Chlorpyrifos is effective on this very rare pest. Currently chlorpyrifos is not specifically labeled for this target, however, its use is allowable according to section 6000 of the California Code of Regulations (Title 3 Food and Agriculture, Division 6). No information on rates is available.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate to severe
Damage	Production of honeydew and sooty mold that can damage leaves and cosmetically damages fruit
Frequent or Occasional Pest	Occasional
Regionality	Mainly Central Valley
Timing of Outbreaks	May- July

Alternative Active Ingredients (AI)

Currently chlorpyrifos is not labeled for this target.

Alternative Management Practices

Practice	Comments
Natural enemies are effective	None noted

Navel Orangeworm
Amyelois transitella

Navel orangeworm (NOW) is a primary pest of almonds in California and is found on several hosts. Eggs are laid on mummy nuts in the trees or on new crop nuts after the initiation of hull split. First-instar larvae bore into the nutmeat; and later instars can consume most of the nut, producing large amounts of webbing and frass. As noted below, NOW larval damage can also lead to fungal infections and aflatoxin issues, a key concern for food safety. Some cultivars are more susceptible to damage, especially later-maturing softshell almonds with a lengthy hull split period or a poor shell seal.

Two cultural practices—1) effective removal and destruction of mummy nuts in fall or winter and 2) rapid, early harvest—provide the most effective control of NOW. In the San Joaquin Valley insecticide treatments are needed even when these practices are carried out properly, especially when infested alternate host trees (fig, pomegranate, or pistachio) are nearby. When alternate host trees are in the vicinity, NOW moths may migrate into almond orchards. Treating border rows may be adequate to prevent the moths from infesting the almond crop when NOW densities are low to moderate. Sprays are timed using egg traps, monitoring of hull split, and/or degree-days. Two parasitic wasps may be found in orchards, but they cannot be relied on to provide effective control alone without other cultural or compatible chemical practices also being used.

Navel orangeworm opens the door to fungal infections and contaminants. Research shows the mold *Aspergillus* and the aflatoxin contaminant it produces is associated with reject kernels, particularly those damaged by navel orangeworm. Aflatoxin produced by *Aspergillus* mold is a known carcinogen and mutagen and is a food safety and foreign trade issue.

Role of Chlorpyrifos: Chlorpyrifos is an important and highly effective IPM tool at a critical time in the season for this major pest. As pyrethroid resistance increases, chlorpyrifos is needed for use in support of mating disruption programs.

There is a need to understand regional differences in pest management for this pest as it appears to vary widely between counties, thus chlorpyrifos use varies greatly. Other active ingredients do not perform as well as chlorpyrifos by air and timing of application is critical.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Severe
Damage	Direct damage to nutmeats
Frequent or Occasional Pest	Frequent
Regionality	Widespread but pressures greater in Southern SJV
Timing of Outbreaks	Hull split; one month before harvest(July – Aug)

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Bacillus thuringiensis kurstaki	Dipel ES	11B	1.90	Weak, issue with efficacy
Bifenthrin	Brigade	3A	1.29	Documented resistance; More broad spectrum, disrupts mites
Chlorantraniliprole	Altacor	28	1.94	Narrow spectrum to worms
Emamectin Benzoate	Proclaim	6	1.41	Narrow spectrum to worms
Esfenvalerate	Asana	3A	0.46	More broad spectrum, disruptive to mites; suspected resistance
Fenpropathrin	Danitol	3A	1.20	More broad spectrum, disruptive to mites; suspected resistance
Flubendiamide	Belt	28	1.29	Narrow spectrum to worms
Lambda - cyhalothrin	Warrior	3A	0.20	More broad spectrum,; suspected resistance
Methoxyfenozide	Intrepid	18	1.80	Narrow spectrum to worms
Phosmet	Imidan	1B	2.27	More broad spectrum, disruptive to mites
Spinetoram	Delegate	5	3.21	Narrow spectrum to worms
Spinosad	Success	5	2.25	Weak
Spinosad	Entrust SC	5	1.01	None noted
Flubendiamide + Buprofezin	Tourismo	Premix 28 & 16	NA	None noted
Chlorpyrifos	Lorsban	1B	1.00	None noted

Alternative Management Practices

Practice	Comments
Mummy nut destruction fall-winter	Sanitation widely practiced but this is still a big problem
Biological control	Not effective or cost effective
Early harvest	Might not be practical
Mating disruption	Needs refinement for local situations

Other Considerations and Knowledge Gaps

Research	Policy	Education
Mating disruption refinement Efficacy data for hull split applications needed Shell-seal evaluation Regionality of pesticide efficacy Impact of low VOC formulations on efficacy Efficacy of aerial applications on large trees Treatment timing Cross resistance in pyrethroids	MRLs need to be established for all pesticides used for this pest.	Spray coverage and timing of ovicides Benefits of monitoring to PCAs Mating disruption Benefits of timely harvest Benefits of sanitation

Peach Twig Borer
Anarsia lineatella

Peach twig borer is a major pest in several tree crops. Larvae damage both growing shoots and nuts, causing shallow channels and surface grooves on the nutmeat. Peach twig borer damage can be mistaken for NOW feeding, which often occurs on nuts previously damaged by peach twig borer.

Some orchards will require a treatment for peach twig borer. Preferred treatment timing is during the dormant period (chlorpyrifos combined with oil sprays, if there is concern for San Jose scale, European red mite, or brown almond mites), delayed dormant or post bloom. Peach twig borer has about 30 species of natural enemies. In some years and orchards, these natural enemies destroy a significant portion of larvae, but they may not reduce twig borer populations below economically damaging levels. Ants, *Formica* spp., also can be found preying on peach twig borer larvae.

Role of Chlorpyrifos: Chlorpyrifos is only one of many products available as a dormant or delayed treatment.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate to severe
Damage	Damage to growing shoots and nuts
Frequent or Occasional Pest	Occasional to frequent
Regionality	Widespread – mainly a northern SJV issue
Timing of Outbreaks	Early season (shoot damage), hull split (direct damage to nuts)

Alternative Active Ingredients (AI) – Base on Spring Treatments, UC IPM PMG

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Acetamiprid	Assail	4A	4.16	None noted
Bacillus thuringiensis	DiPel ES	11B	1.90	None noted
Chlorantraniliprole	Altacor	28	1.16	None noted
Emamectin Benzoate	Proclaim	6	1.41	None noted
Flubendiamide	Belt	28	1.29	None noted
Flubendiamide + Buprofezin	Tourismo	Premix 28 & 16	NA	None noted
Spinetoram	Delegate	5	1.24	None noted
Spinosad	Success	5	2.25	None noted
Spinosad	Entrust SC	5	2.61	None noted
Chlorpyrifos	Lorsban	1B	1.00	None noted

Alternative Management Practices

Practice	Comments
Mating disruption	Severity of PTB doesn't really warrant use
Conservation of natural enemies	Pyrethroids used at dormant timing can affect non-target organisms, especially natural enemies of mites but adverse impacts may be managed. Pyrethroids have off site water quality issues and there is also potential for resistance.

San Jose Scale

Diaspidiotus (= Quadraspidiotus) perniciosus

Scales suck plant juices from twigs and limbs and inject a toxin, resulting in loss of tree vigor, growth and productivity, and death of limbs. A red halo is produced around a feeding site on 1 year old green wood. Untreated infestations can kill fruit spurs and scaffold wood within 1 to 3 years.

San Jose scale has many natural enemies that commonly keep the pest under control if not disrupted by in-season applications of broad-spectrum insecticides. Many orchards that have not used broad-spectrum sprays for 2 or 3 years do not have San Jose scale problems. Low to moderate populations can be managed with oil sprays during the dormant season. The best time to spray is during the dormant season, and low to moderate populations can be managed with oil sprays at this time. The scale is monitored as part of the spur sample during the dormant season and with pheromone traps in the spring.

Predators and parasites are helpful in reducing scale populations; but insecticides used during the growing season for other pests disrupt this natural control, and scale populations can build as a result. Low winter mortality due to mild temperatures will also permit a buildup of scale populations.

Role of Chlorpyrifos: Primarily used as a dormant treatment with oil.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate to severe
Damage	Scales suck plant juices from twigs and limbs, and inject a toxin, resulting in loss of tree vigor, growth and productivity, and death of limbs.
Frequent or Occasional Pest	Occasional
Regionality	Widespread, but more problematical in Southern SJV
Timing of Outbreaks	NA

Alternative Active Ingredients (AI) : Base on Spring Treatments, UC IPM PMG

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Buprofezin	Centaur WDG	16	4.45	
Pyriproxyfen	Sieze 35WDG	7C	1.74	Expensive; effective on small nymphs; soft on beneficial sand treatment only necessary occasionally
Narrow range oil (dilute)	Omni Supreme and others	UC	0.60	

Alternative Management Practices

Practice	Comments
Conservation of natural enemies	None noted

Other Considerations and Knowledge Gaps

Research	Policy	Education
Monitoring programs	MRLs need to be established for all pesticides used for this pest.	PCA training on trapping SJS and parasitoids with pheromone traps PCA training on spur sampling and identification of parasitized scale Use of products that are soft on beneficials

Leafrollers

Fruittree leafroller: *Archips argyrospila*
Obliquebanded leafroller: *Choristoneura rosaceana*

Leafrollers are occasional pests of almonds. The primary damage occurs early in the season when larvae of the overwintered generation feed on developing nuts. Many of the damaged nuts are lost in the June drop, presumably reducing yield. The summer generation of the obliquebanded leafroller ties leaves and nuts together and feeds on the hulls. Leafrollers feed on the hulls leading to increased NOW nut infestation.

Role of Chlorpyrifos: There is concern that as utilization of mating disruption increases, leafrollers will become more of a problem. Chlorpyrifos is an effective material for controlling this pest. Currently chlorpyrifos is not specifically labeled for this target, however, its use is allowable according to section 6000 of the California Code of Regulations (Title 3 Food and Agriculture, Division 6).

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate
Damage	Shoot wilting and die-off, hull, kernel and shell feeding, nut damage
Frequent or Occasional Pest	Occasional
Regionality	All of San Joaquin Valley
Timing of Outbreaks	Unknown

Alternative Active Ingredients (AI)
Currently chlorpyrifos is not labeled for this target.

Alternative Management Practices: None noted

Other Considerations and Knowledge Gaps

Research	Policy	Education
Alternative controls need testing	None noted	Correct pest identification

Fuller Rose Beetle

Naupactus godmanni

The Fuller Rose Beetle beetle does not cause economic damage in almonds, but adults lay eggs in microsprinklers. This species can be a quarantine concern.

Role of Chlorpyrifos: Highly effective contact spray to kill adult beetles before they lay eggs in microsprinkler orifices. Currently chlorpyrifos is not specifically labeled for this target, however, its use is allowable according to section 6000 of the California Code of Regulations (Title 3 Food and Agriculture, Division 6).

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate
Damage	Clogs irrigation equipment
Frequent or Occasional Pest	Occasional
Regionality	Southern San Joaquin Valley
Timing of Outbreaks	July - September

Alternative Active Ingredients (AI): None noted.

Alternative Management Practices: None noted

Other Considerations and Knowledge Gaps: None noted

Ten-Lined Beetle

Polyphylla decemlineata
Polyphylla sobrina

Larvae feed on roots, causing severe injury and death to mature trees. Initial damage to root systems may not be immediately evident in above-ground tree growth (e.g., production of new shoots and leaves). Adults cause no damage. Ten-lined June beetle infestations are localized within orchards and are often first noticed when a clump of trees start to decline and die. Infestations usually spread slowly from the initial sites where they are first identified in orchards, killing neighboring trees. Weakened root systems can cause entire trees to topple. Control requires the removal of infested trees and soil fumigation before replanting.

Role of Chlorpyrifos: It has been observed that soil drenches of organic insecticides as soon as first adults emerge can reduce populations. Currently chlorpyrifos is not specifically labeled for this target, however, its use is allowable according to section 6000 of the California Code of Regulations (Title 3 Food and Agriculture, Division 6).

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate
Damage	Root feeding can lead to injury and death of trees
Frequent or Occasional Pest	Occasional
Regionality	Areas with sandy soils in the Central Valley
Timing of Outbreaks	Ongoing – underground feeding by larvae

Alternative Active Ingredients (AI)
Currently chlorpyrifos is not labeled for this target.

Alternative Management Practices

Practice	Comments
Remove infested trees	

Other Considerations and Knowledge Gaps: None noted

Tree Borers

American plum borer: *Euzophera semifuneralis*
Peach Tree Borer: *Synanthedon exitiosa*
Prune limb borer: *Bondia comonana*

Prune limb borer, peach tree borer, and American plum borer are sporadic pests in both young and mature almond orchards (bark injuries). They occur from Tehama to Merced counties on all major almond cultivars, but in young trees are found mostly on Carmel, Sonora, and Price.

Larvae bore into trees leaving reddish orange frass and gum pockets. The boring is most damaging to the scaffold crotches or graft unions of young trees. Vigorous growing trees will heal over; but with heavy, prolonged infestations, scaffolds may break with wind or a heavy crop. Boring in callus tissue formed under trunk-shaker bark injuries can greatly enlarge the initial injury and also introduces spores of the *Ceratocystis* canker fungus, leading to subsequent trunk cankers that can girdle scaffolds and may ultimately lead to tree death.

Role of Chlorpyrifos: Chlorpyrifos is only occasionally used as this pest is generally controlled with other products used for other pests. This is mostly an issue on young trees.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate
Damage	Larvae bore into trees and can introduce fungus; branches break, tree death
Frequent or Occasional Pest	Occasional
Regionality	Northern to Central SJV
Timing of Outbreaks	Very localized occurrence

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Bifenthrin	Brigade	3A	NA	Pest not on label
Carbaryl	Sevin	1B	1.45	Note noted
Beta-cyfluthrin	Baythroid	3A	NA	Pest not on label
Esfenvalerate	Asana	3A	NA	Pest not on label
Lambda - cyhalothrin	Warrior	3A	NA	Pest not on label
Chlorpyrifos	Lorsban	1B	1.00	None noted

Citrus Crop Team Report

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Judy Zaninovich, CA Citrus Pest and Disease Prevention Program

Overview

The Citrus Crop Team identified a total of 14 pests as important species for which chlorpyrifos is a key component of their IPM programs. In all production areas, chlorpyrifos is central for ant control, especially liquid sugar feeding ants that protect hemipteran pests from natural enemies. Chlorpyrifos will remain an essential tool until new, effective active ingredients are registered for use for this ant group. For other pests, there are alternatives to this active ingredient, however, it is considered a superior choice preferred by growers due to its efficacy, spectrum of activity on multiple pests, cost profile and because many natural enemies have developed resistance to it.

Introduction and Background

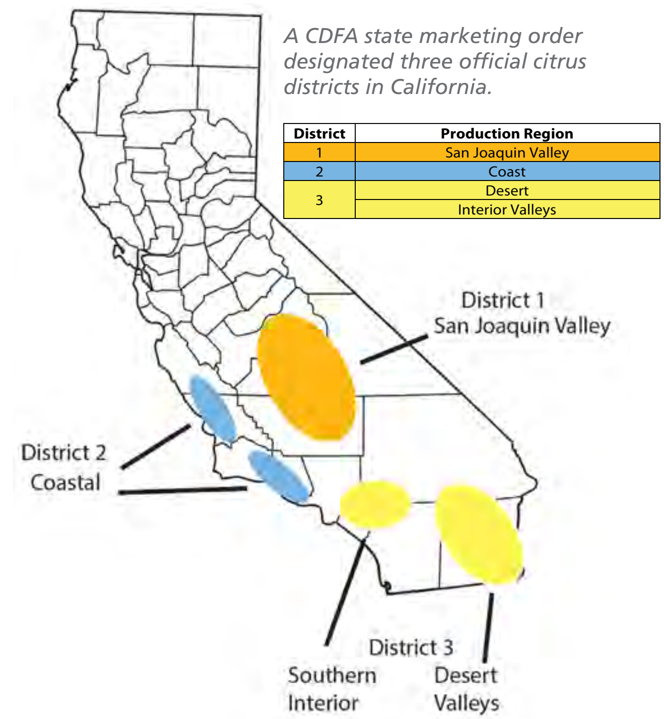
California citrus production includes oranges, mandarins, lemons, grapefruit, and exotic fruits grown in four unique production regions throughout the state (Figure 4.1). In 2013, California produced $2.4 billion of citrus from 254,000 acres of orchards. Oranges ranked 7th in value among commodities grown in California with a significant portion of the crop going to Canada, South Korea, China, Japan, Australia and New Zealand.

In California, chlorpyrifos is considered an essential IPM tool that PCAs and growers know that, when used infrequently or used at low rates, can effectively control a critical pest problem, while allowing natural enemies to survive to help with control of other pests. Chlorpyrifos is unique in the arsenal of citrus crop protection insecticides because of its ability to "clean up" critical problems without destroying the IPM program.

With the expansion of free trade and a mobile society, invasive pests are a frequent and recurring problem. These pests arrive without any natural enemies and can increase to damaging levels quickly. Chlorpyrifos is a broad-spectrum material that can be used to quickly and effectively control these invasive pests at the same time growers are treating other pests. If those treatments are needed near harvest, chlorpyrifos has well-established MRLs that allow the fruit to be exported. Controlling multiple pests with one application has many benefits including reductions in costs, overall pesticide use, and trips through the field that can increase fruit damage, soil compaction and air pollution.

California Citrus Production

- 250,000+ acres
- $2.4 Billion dollars
- Includes oranges, mandarins, lemons, grapefruit and exotics



District	Production Region
1	San Joaquin Valley
2	Coast
3	Desert
	Interior Valleys

Figure 4.1. Citrus production areas in California. Modes of action refer to the Insecticide Resistance Action Committee (IRAC) classification (www.irac-on-line.org.)

Multiple Varieties and IPM Approaches

- San Joaquin Valley: The majority (>75%) of California's citrus acreage is produced here. Breakouts by variety in this region are: 78% oranges, 16% mandarins, 5% lemons, with grapefruit and exotics making up the difference. This region has the greatest extremes of temperature and the most difficulty with biological control of pests.

- Coastal: Approximately 15% of the total citrus acreage, comprised of 63% lemons, 28% oranges, with the remainder split between mandarins and grapefruit. The climate is coastal with fog and ocean breezes keeping the temperatures moderated.   Lemons have unique pests such as citrus bud mite that must be controlled with insecticides.

- Desert Valleys: ~5% of California's citrus including lemons, navel oranges, Valencia oranges, and mandarins.

- Southern Interior: ~5% of the total crop is grown in San Bernardino, Riverside and San Diego Counties. Biological control has traditionally been quite successful in this region

Citrus Integrated Pest Management (IPM)

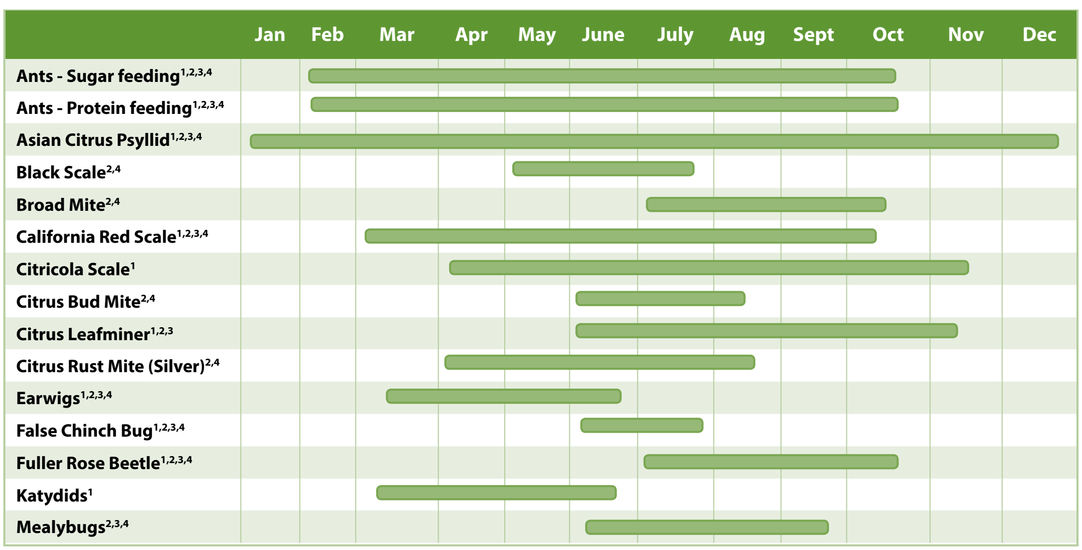
Citrus has a long and proud history in entomology and integrated pest management. The field of biological control was born in Riverside with the successful introduction of the Vedalia beetle for control of the cottony cushion scale in citrus in the early 1900's. Decades of biological control research have rendered many scales, whiteflies and other insect groups insignificant pests in California. Pests that are not well-controlled by biological control tend to be the drivers of pesticide use.

The citrus industry strives to manage pests in ways that are economical and sustainable with judicious use of broad-spectrum pesticides and maximum use of natural enemies. The citrus community has developed programs to address pesticide resistance, worker safety, and environmental issues through grower-funded programs and initiatives. The Citrus Research Board and the Citrus Quality Council coordinate efforts to ensure that California citrus production meets domestic and international phytosanitary, food safety, food additive, and pesticide residue requirements.

Citrus hosts a complex of pests requiring local decision making and extraordinary pest management knowledge. In general, control of pests is easier to achieve in coastal and inland Southern California areas due to milder temperatures, which leads to better control by beneficial insects. In the San Joaquin Valley, extremes of heat and cold reduce the efficacy of natural enemies. Populations of pests such as katydids and citricola scale that are not regulated by natural enemies require insecticide treatments. Chlorpyrifos plays a very important role in this region because organophosphates have been used for many years and many of the natural enemies, especially Vedalia beetle needed for cottony cushion scale control, predatory mites needed for thrips and mite control and even hymenopteran parasites for California red scale control have developed some level of resistance to chlorpyrifos. Thus, when used infrequently and/or at low rates, chlorpyrifos is an IPM tool, regulating one or more pest populations but allowing natural enemies to survive to assist with control.

Because of differences in pests in the various Districts and in uses of chlorpyrifos, the Citrus Crop Team requested their information be presented by region in terms of crop production, pest occurrence, and IPM approaches. Discussions included representatives from all three citrus districts.

The seasonal occurrence of the prominent pests is shown in Figure 4.2 and historical information on the use of chlorpyrifos (2002-2012) is shown in Figures 4.3 and 4.4.



Areas of pest occurrence: [1]San Joaquin Valley, [2]Coast, [3]Desert, [4]Southern Interior.

Figure 4.2. Seasonality of citrus pests. If the average cost per acre is equal to the price of chlorpyrifos, the value would be 1.0.

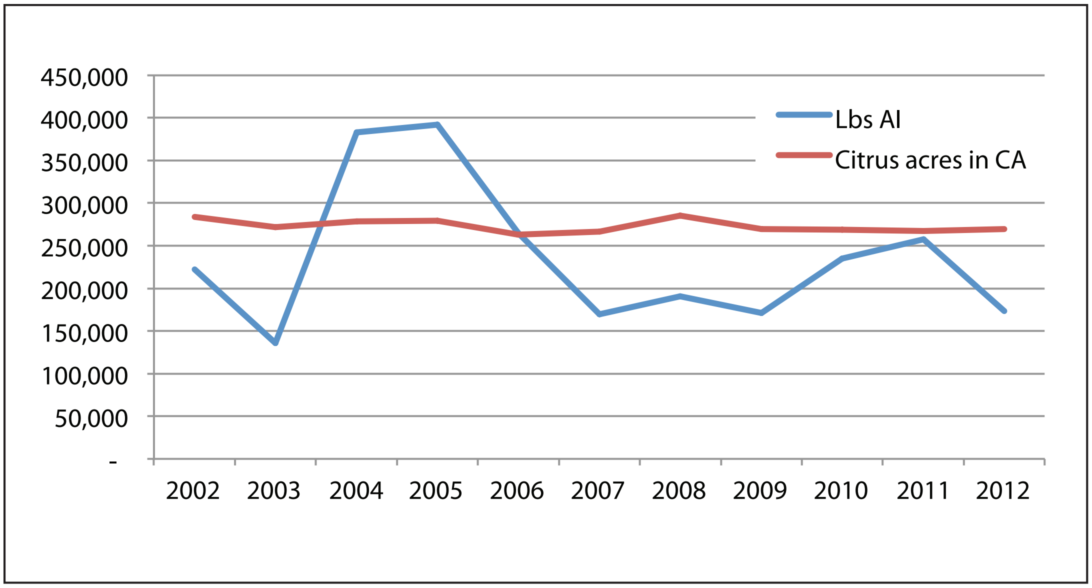


Figure 4.3. Chlorpyrifos use and acres of citrus (2002 – 2012). (Source: CDPR PUR & CASS)

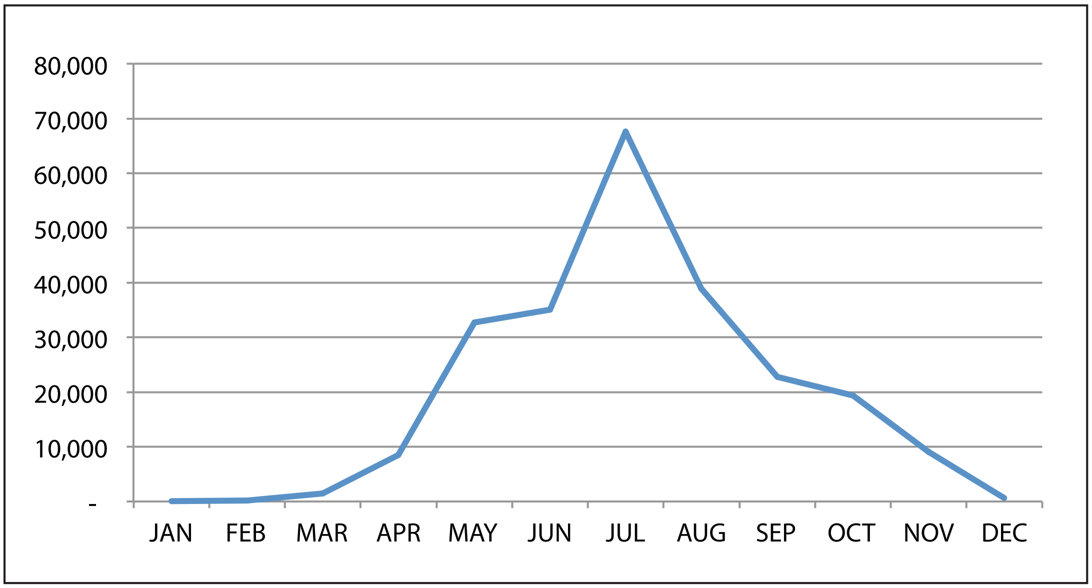


Figure 4.4. Average monthly use (lbs) of chlorpyrifos in California citrus (2002-2012). (Source: CDPR PUR)

Key Points to Consider Regarding Citrus IPM

• Citrus is a complex crop with regional IPM programs that, if over-simplified, could lead to ineffective control, multiple treatments for multiple pests, and subsequently negative environmental impacts.

• When managing citrus pests, treatment options are not considered in isolation. Depending on variety, citrus can be on the tree up to eighteen months from bloom to harvest. Growers must consider what has already been applied and what pest control needs may arise later in the season. Decisions are made in the context of a season long program.

• California citrus currently has relatively low pesticide use as compared to other production areas in the US. An average of four treatments per year is considered very low for a tree crop.

• Citrus experiences the highest rate of chlorpyrifos per application of any crop because complete coverage of branches, trunk and dense foliage with high water volumes (>500 gpa) is needed.

Criticality of Chlorpyrifos in Citrus IPM

Chlorpyrifos is one of several active ingredients pest control advisors recommend for citrus pest control. During the group process of reviewing critical uses of chlorpyrifos, fourteen insect pests emerged as the most important in terms of using chlorpyrifos (Table 4.1). Of these, two were considered **Key** with few or no alternative products (dependent on production area) and twelve were considered **Important**, but alternative active ingredients were available. The Citrus Crop Team determined they would not list any pests as "**Occasional**" because several species originally classified in this category were ultimately determined to be too occasional or localized to note (as opposed to the Alfalfa, Almond and Cotton Crop Teams that included this classication). Due to this, only those citrus pests considered "Key" and "Important" are listed on the tiered Critical Use Matrix (Table 4.1). Pest damage and occurrence is captured in the Pest Profiles section at the end of the Crop Team report.

Critical Uses of Chlorpyrifos in San Joaquin Valley Citrus			District 1
Criticality Tier	**Pest**	**Number of Modes of Action in Addition to Chlorpyrifos**	**Alternative Practices Available**
Key Pests with No Alternatives	Ants – sugar feeding	0	No
Important Pests with Alternatives	Ants – protein feeding	3	No
	Asian Citrus Psyllid	14	No
	California Red Scale	5	Limited
	Citricola Scale	3	Limited
	Citrus Leafminer	6	No
	Earwigs	1	Limited
	Fuller Rose Beetle	5	Limited
	Katydids	4	No
Occasional Pests with Alternatives	None noted (too occasional or localized)	NA	NA

Critical Uses of Chlorpyrifos in Coastal Citrus			District 2
Criticality Tier	**Pest**	**Number of Modes of Action in Addition to Chlorpyrifos**	**Alternative Practices Available**
Key Pests with No Alternatives	Ants – sugar feeding	0	No
Important Pests with Alternatives	Ants – protein feeding	3	Limited
	Asian Citrus Psyllid	14	No
	Black Scale	2	Limited
	Broad Mite	5	Limited
	California Red Scale	5	Limited
	Citrus Bud Mite	5	No
	Citrus Leafminer	6	No
	Earwigs	5	No
	Fuller Rose Beetle	1	Limited
Occasional Pests with Alternatives	None noted (too occasional or localized)	NA	NA

Critical Uses of Chlorpyrifos in Desert and Inland Valley Citrus			District 3
Criticality Tier	**Pest**	**Number of Modes of Action in Addition to Chlorpyrifos**	**Alternative Practices Available**
Key Pests with No Alternatives	Ants – sugar feeding	0	No
	Ants – protein feeding	3	No
Important Pests with Alternatives	Asian Citrus Psyllid	14	No
	Black Scale	2	Limited
	Broad Mite	5	Limited
	California Red Scale	5	Limited
	Citrus Bud Mite	5	No
	Citrus Leafminer	6	No
	Citrus Rust Mite (Silver Mite)	5	No
	Earwigs	1	Limited
	Fuller Rose Beetle	5	Limited
	Mealybug	1	Yes
Occasional Pests with Alternatives	None noted (too occasional or localized)	NA	NA

Table 4.1 Critical uses of chlorpyrifos in three California citrus districts.

Chlorpyrifos Use Pattern

Chlorpyrifos is seldom the first material selected in a citrus IPM program. (Appendix 5) Under certain conditions when a combination of pests threaten the crop or if a successful ongoing IPM program is threatened by a particular pest that needs to be knocked out quickly, chlorpyrifos is considered an essential crop protection tool. The following are four examples of circumstances that make chlorpyrifos the best insecticide choice.

Situation 1: Selectivity Favoring Natural Enemies

When katydids appear in the San Joaquin Valley at petal fall, they can cause significant damage in a short period of time. They are easily killed by very low rates of chlorpyrifos (<0.5lbs AI/acre). This rate has little impact on the natural enemies of other pests. Alternative chemistries lack this selectivity or do not kill the katydids quickly enough.

Situation 2: Multiple Pests

Late in the season in the San Joaquin Valley, fruit that is shipped to Korea must be treated to prevent Fuller rose beetle egg infestations. If heat units have been excessive (2012-2014) and a California red scale population has increased to the point that it requires a late season treatment, chlorpyrifos is the only insecticide that will kill both California red scale and Fuller rose beetle at that time of year. Separate treatments for the two pests would be costly, increase air pollution produced by equipment, and disrupt natural enemies. This example also points out that export country demands sometimes dictate mandatory insecticide treatments that are not part of the normal IPM program.

Situation 3: Invasive Pests

In California citrus, chlorpyrifos may be the best choice for regulating new invasive pests at certain times of year. For example, Asian citrus psyllid (ACP) has recently invaded California and potentially vectors a deadly bacterial disease. The ideal time for treating to have the greatest impact on the population is as the psyllid begins to overwinter and as attacks leaf flush in the spring and fall. Chlorpyrifos is a good choice for a fall treatment because it has international MRLs established, it acts quickly, it is relatively safe for natural enemies such as parasites and predators and it is more efficacious than alternative pesticides.

Situation 4: Ants

Alternatives to chlorpyrifos do not control ants and if ants are not controlled secondary pests such as mealybugs become serious pests. Periodic treatments with chlorpyrifos help keep ants under control.

According to data from CDPR Pesticide Use Reports during the period 2002-2012, chlorpyrifos use peaked in 2005 and has fluctuated around 230,000 lbs per year between 2007 and 2012 (Figure 4.3) with the average monthly use peaking in July (Figure 4.4).

District 1 has the greatest number of acres treated with chlorpyrifos (Figure 4.5), because that is where the majority the citrus is grown and because chlorpyrifos is used for Citricola scale, a pest not found in the other regions. Fig. 4.6 shows that lbs AI/acre chlorpyrifos is low in the District 3 interior valleys of southern California (averages less than 1 lb AI per acre). Chlorpyrifos use fluctuates in response to the appearance of California red scale, which is under eradication in the District 3 desert (averages 2 lbs AI/acre).

In District 2 chlorpyrifos is primarily used to control citrus bud mite on lemons at an average rate of 3 lbs AI/acre. District 1 also averages 3 lbs AI/acre, but use rates have been separated out in Figure 4.7 to show that use depends on this specific target pest. Chlorpyrifos is applied at rates of < 0.5 lbs AI/acre for pests that require 100-200 GPA water volume for outside coverage of the tree, such as katydids and psyllids. For pests that require interior coverage of the tree (300-500 GPA), such as Fuller rose beetle, citrus bud mite, and citricola scale, the rate is 1- 3 lbs AI/acre. For California red scale, the rate is between 3-6 lbs AI/acre, because of the very high water volume (750-1000 GPA) needed to cover the interior and trunk of the tree. Peak use of the higher rates of chlorpyrifos was in 2004 and 2005 in the San Joaquin Valley (Figure 4.7).

In 1998, the insect growth regulator pyriproxyfen was registered and treatments with this AI replaced chlorpyrifos treatments for California red scale. However, pyriproxyfen was not effective against citricola scale in this region and populations of that pest increased during 1999-2004 throughout the San Joaquin Valley. Growers responded to the citricola scale with chlorpyrifos treatments, which at the time was the most effective insecticide.

In later years, neonicotinoid insecticides became available and chlorpyrifos use declined. Increases of chlorpyrifos noted in recent years are due to disruption of California red scale by weather and increased use of neonicotinoids, which are not effective in controlling California red scale. In fact, chlorpyrifos is a better IPM tool in this situation, because it is more selective favoring natural enemies than the neonicotinoids. This is an example of the continual changes in pest pressures in citrus that require a rapid response and demonstrates how chlorpyrifos provides an IPM solution.

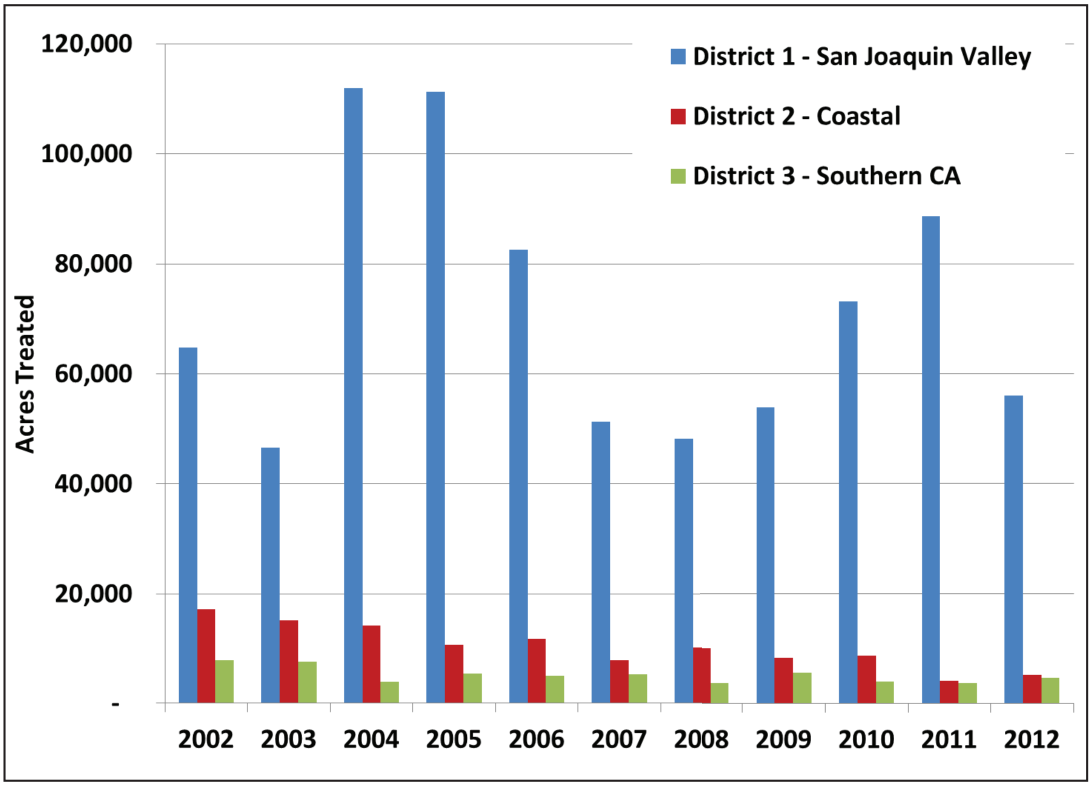


Figure 4.5. Number of acres treated with chlorpyrifos in three citrus districts (2002-2012).

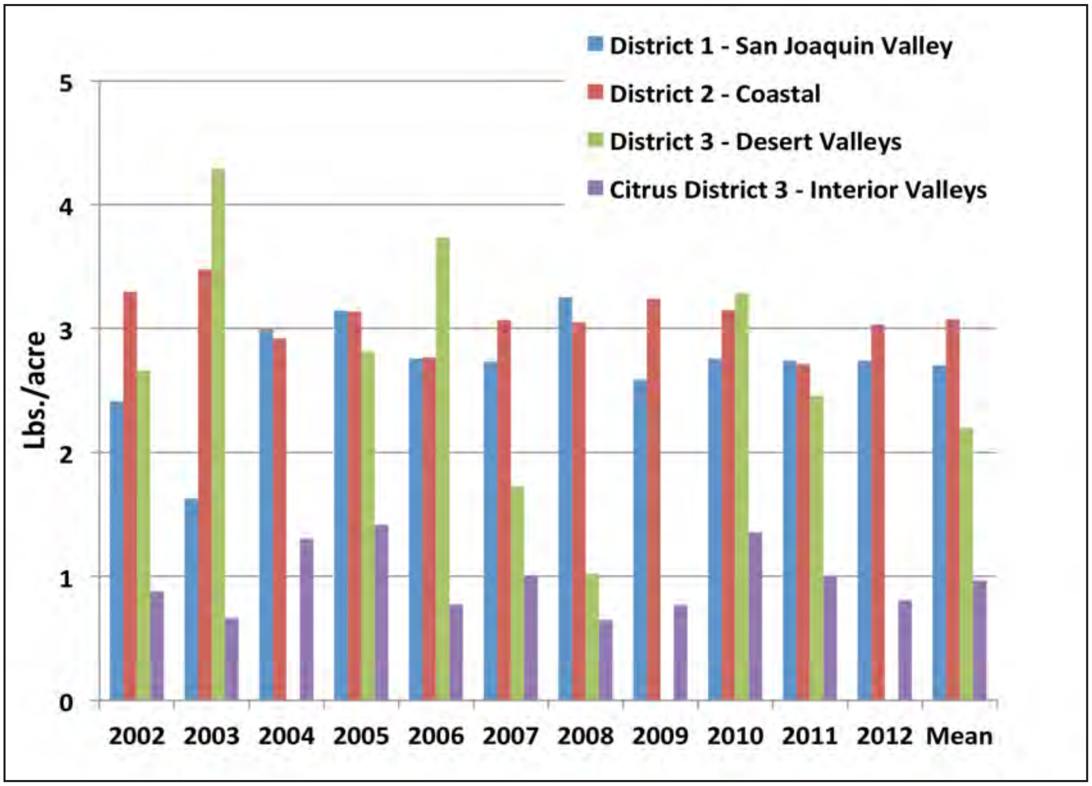


Fig. 4.6. Chlorpyrifos use in three citrus districts (2002-2012)

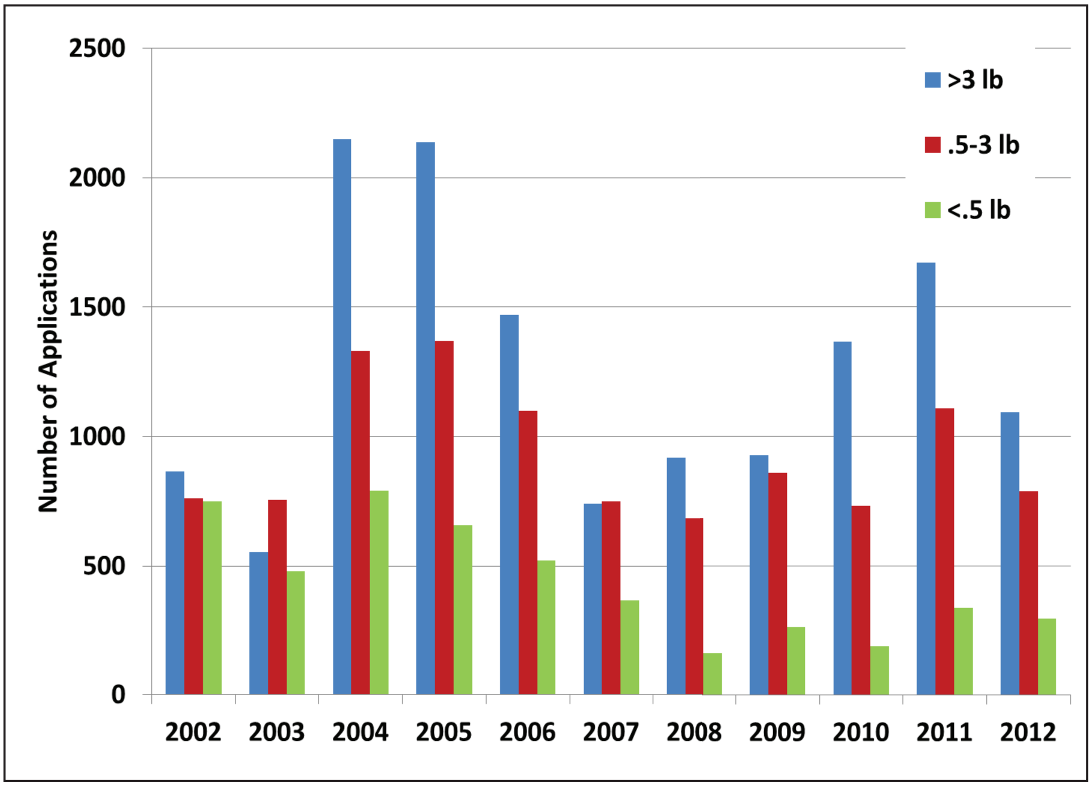


Figure 4.7. Number of chlopyrifos applications in San Joaquin Valley citrus at low (<0.5lb), medium (0.5-3 lb) and high (>3 lbs) AI per acre rates (2002 - 2012).

Cost of Alternative Active Ingredients

The Citrus Crop Team emphatically stressed that "fit" within each regional IPM program was the most important issue in the decision making process to potentially use chlorpyrifos, not simply the cost of the products used.

There was a wide range of expense for alternative active ingredients, depending on cost of product and the recommended rates per acre. The application cost must also be considered which is higher when large volumes are required to effectively distribute the AI. Total spray volume is therefore a factor when considering treatment alternatives in citrus.

Table 4.2 presents the relative costs of alternative AIs to chlorpyrifos for control of citrus pests. The range of relative costs varied between a low 0.11 the cost of chlorpyrifos to a high of 7.67 Details of alternative active ingredients can be viewed individually in the Pest Profiles section.

Tier	Pest	Low	High	Comment
1	Ants, Sugar Feeding	NA	NA	Ground spray
	Ants, Protein Feeding	NA	NA	Baits and ground spray
2	Asian Citrus Psyllid	0.31	6.19	In-season in rotation with other materials
	Broad Mite	0.11	5.64	Useful when several pests present
	Black Scale	1.94	5.66	Useful when several pests present (e.g. CRS)
	CA Red Scale	1.09	7.67	Useful when several pests present (e.g. Citricola scale)
	Citricola Scale	2.01	5.66	Useful when several pests present (e.g. CRS)
	Citrus Bud Mite	1.19	5.66	Useful when several pests present (e.g. CRS)
	Citrus Rust Mite (Silver)	0.57	3.13	Fall application; useful when several pests present
	Citrus Leafminer	NA	NA	Chlorpyrifos not labeled for pest
	Earwig	NA	NA	Chlorpyrifos not labeled for pest.
	Fuller Rose Beetle	0.22	2.90	Pest is export issue, other pests controlled
	Katydids	0.27	1.64	Effective at low rates
	Mealybug	2.95	2.95	Biological control is effective
	Summary	**0.11**	**7.67**	

Table 4.2. Relative costs of alternative AIs compared to chlorpyrifos for citrus. If the average cost per acre is equal to the price of chlorpyrifos, the value would be 1.0.

Gaps in Research, Extension and Policy

The Citrus Crop Team identified the following research, extension and policy needs relative to chlorpyrifos use. These are presented in no specific order of priority and will require coordinated efforts of industry, educational and government personnel.

Research Needs

• *Strengthen scientifically verified and peer reviewed data on human and environmental risks associated with chlorpyrifos*

• *Develop methods for controlling sugar feeding ants*

• *Asian citrus psyllid management in the context of IPM*

• *Develop additional data for products that have VOC restrictions and are used for broad mites*

• *Conduct efficacy studies for spirodiclofen (Envidor) and fenpyroximate (Fujimite)*

• *Evaluate black scale insecticides*

• *Evaluate chlorpyrifos versus spirotetramat (Movento) for broad mites*

• *Conduct additional research on spirotetramat (Movento) and pyriproxyfen (Esteem) to improve control of California red scale*

• *Ensure that chemical companies test their AIs against all relevant citrus pests to ensure that a comprehensive label is developed*

• *Evaluate and compare use of abamectin and chlorpyrifos for bud mite*

• *Develop organic options for all pests.*

"The real question is how do we minimize pesticide use, maximize efficacy and comply with MRL requirements?"

Extension Needs

The University of California has a strong citrus extension education program in the form of grower seminar presentations, Web pages (UC IPM guidelines and citrus entomology websites), books (Citrus IPM manual, production manual), brochures (UC ANR), online courses, in-depth workshops, field days, and blogs. Information specific to chlorpyrifos can be readily incorporated into these outreach programs and products. A full list of resources is provided before Appendices. The following outreach activities related to chlorpyrifos stewardship are ongoing and will continue to emphasize:

• *Foster a new generation of citrus IPM experts through training and mentoring*

• *Provide regional training on IPM including pest identification, pest monitoring, preservation of natural enemies and best options to manage multiple pests*

• *Provide training on how in-season treatments impact the marketer, grower, and packing house at harvest and when product is exported many months later*

• *Provide training on nuances in the decision making process when chlorpyrifos may be an option*

• *Provide training to clearly articulate regulatory concerns associated with chlorpyrifos*

• *Provide training to address ground, air, and/or worker exposure associated with chlorpyrifos use*

• *Communicate that the Citrus IPM Guidelines or the insecticide label can justify a use for a particular pest*

• Educate growers and PCa's about organic options.

Policy Needs

MRL harmonization and risk assessments emerged as the major policy areas highlighted by the Citrus Crop Team.

Maximum residue limits (MRLs) for citrus are critical because a significant percentage of the crop is exported (20-40%). Because chlorpyrifos was registered many years ago, MRLs have established for a long time. For newer chemistries, this is not the case and pesticide manufacturers are currently working to prioritize active ingredients within Codex and in specific countries (Korea, Japan, Taiwan, etc.). If MRLs are not set for a product in an importing country, the product cannot be used because the risk of detection of residues and rejection of the load is too high. In some countries markets may be closed if there are violations.

• *Establish MRLs for all new citrus registrations in US (registrants and US EPA)*

• Expedite the international regulatory harmonization and registration process for MRLs (US EPA and USDA)

Additional scientific data is needed to assess risks associated with chlorpyrifos use. This information should be shared in a clear and meaningful way to all stakeholders (CDPR).

• Articulate specific concerns associated with ground, air, and or worker exposure related to chlorpyrifos applications (CDPR)

• Enlighten the public about treatment decisions and trained and licensed personnel involved in chlorpyrifos use (all stakeholders)

Potential Funding Sources for Citrus IPM

The Citrus Crop Team identified potential sources of funding to support research and outreach projects related to chlorpyrifos use in IPM systems.

Source	Organization and/or Program
Commodity	Citrus Research Board
State	CDFA Specialty Crop Block Grant Program CA Department of Pesticide Regulation - Research grants and Pest Management Alliance Program
Federal	EPA IR-4 Minor Use Registration Program USDA-FAS Technical Assistance to Specialty Crops (TASC) USDA Multi Agency Coordination (MAC) USDA-Natural Resources Conservation Service (NRCS) USDA Crop Protection and Pest Management (CPPM) USDA Pest Management Alternatives (PMAP) USDA Integrated Organic Program (IOM) USDA National Extension Integrated Pest Management Projects Program (EIPM) USDA Sustainable Agriculture Research and Education (SARE) USDA Specialty Crop Research Initiative (SCRI)
Regional	Western Region IPM Center - Work Groups and Pest Management Strategic Plans
Corporate	Pesticide manufacturers Farming organizations

Best Management Practices (BMPs) to Mitigate Use of Chlorpyrifos in Citrus

When planning for possible chlorpyrifos applications in an IPM program, consult the UC IPM Guidelines and consider the following Best Management Practices. For additional information, refer to the "Resources" section at the end of this document.

Consider water management practices that reduce pesticide movement off-site:

- ☐ Refine water use through monitoring of using soil moisture and evapotranspiration (ET).
- ☐ Install an irrigation recirculation or storage and reuse system.
- ☐ Use drip rather than sprinkler or flood irrigation.
- ☐ Consider the use of cover crops.
- ☐ Consider vegetative filter strips or ditches.
- ☐ Install sediment traps.
- ☐ Use polyacrylamide in furrow irrigation systems to prevent off-site movement of sediments.
- ☐ Apply polyacrylamides in sprinkler irrigation systems to prevent runoff.
- ☐ Redesign inlets and outlets into tailwater ditches to reduce erosion.

Consider management practices that reduce air quality problems.

- ☐ When possible, reduce volatile organic compound (VOC) emissions by decreasing the amount of pesticide applied, choosing low-emission management methods, and avoiding emulsifiable concentrate (EC) formulations.
- ☐ Use the CDPR calculators to determine VOC emission rates from fumigant and nonfumigant pesticides.

Choose a pesticide from the UC IPM Almond PMG for the target pest, considering:

- ☐ Impact on natural enemies and honey bees.
- ☐ Potential for water quality problems using the UC IPM WaterTox database.
- ☐ Impact on aquatic invertebrates.
- ☐ Chemical mode of action (based on efficacy, spectrum of activity, and pesticide resistance). Select an alternative chemical or nonchemical treatment when resistance risk is high.

Before an application:

- ☐ Ensure that spray equipment is properly calibrated to deliver the desired pesticide amounts for optimal coverage.
- ☐ Minimize off-site movement of pesticides:
- ☐ Use appropriate spray nozzles and pressure.
- ☐ Avoid spraying during conditions conducive to drift or runoff.
- ☐ Identify and take special care to protect sensitive areas surrounding the 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:

- ☐ Record application date, product used, rate, and location of application.
- ☐ Follow up to confirm that treatment was effective.

Pest Profiles

As a part of the critical use discussions, the Citrus Crop Team identified a list of important pests for which chlorpyrifos is considered an important pest management tool.

In order to characterize these pests, general information on the role of this product in IPM, damage, seasonality, frequency and severity of pest outbreaks has been summarized for each species. In addition, information on cost and effectiveness of alternative products and management practices for each pest were assembled in order to have a basis for evaluation and comparison.

This information has been presented in a standardized format simply to describe the role of chlorpyrifos in IPM for the purpose of this project. For detailed information on pest biology, damage and pesticide usage, the UC IPM Pest Management Guidelines for citrus production and CDPR Pesticide Use Report are recommended.

The following section presents pests identified by the Citrus Crop Team. The pests are presented in order of the criticality ranking determined by the team.

Ants – Protein Feeding

Red imported fire ant: *Solenopsis invicta*
Southern fire ant: *Solenopsis xyloni*

Fire ants, both native southern and red imported, directly damage plants by chewing twigs and tender bark of newly planted trees; they also sting people working in the orchard and may cause allergic reactions. Red imported fire ants can also plug up irrigation sprinklers and they have been demonstrated to protect pests, especially honeydew producing scales, whiteflies, aphids, and psyllids from natural enemies.

Role of Chlorpyrifos: Lorsban granular is effective when applied to the ground and liquid spray is used inside tree wraps. Toxicants mixed with baits are available that are formulated with soy oil on corn cob grits as the attractant, however they are slow acting. Lorsban is needed in situations where rapid control is necessary – such as fire ant girdling of young trees.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate to Severe
Damage	Direct feeding on twigs and bark; damage to irrigation system, loss of biological control
Frequent or Occasional Pest	Frequent
Distribution	Fire ant is found throughout S. California. Imported red fire ant is only established in a few areas in S. California
Timing of Outbreaks	March - October

Alternative Active Ingredients (AI) and Resistance Management Issues

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Chlorpyrifos	Lorsban 15G	1B	1	Effective
Pyriproxyfen	Esteem ant bait	7C	NA	None noted
Abamectin	Clinch ant bait	6	NA	Slow acting

Alternative Management Practices

Practice	Comments
Use baits in early summer when ant mounds become active.	Apply baits in the early morning or evening when they are most active so that the bait is quickly taken into the mound. Baits are preferred control tactic because they are fed to the colony and exert longer term control than chlorpyrifos.
Skirt Pruning and sticky materials	Extremely labor intensive and impractical for commercial citrus and stickem can damage trees
Cultivation	Dust can disrupt biocontrol of other pests
Plant bud union high, keep basal trunk dry	None noted
Remove trunk wraps promptly	None noted

Other Considerations and Knowledge Gaps

Research	Policy	Education
Need field data for efficacy of Seduce, Nealta and Agri-Flex as potential alternatives	None noted	None noted

Ants – Sugar Feeding

Argentine ant: *Linepithema humile*
Native gray ant: *Formica aerate*

There are many sugar-feeding species of ants; however two are most prevalent, Argentine and native gray. These ants feed on honeydew excreted by various soft scales, mealybugs, cottony cushion scales, whiteflies, and aphids. As part of this relationship, they also protect these insects from their natural enemies, thus interrupting biological control of the honeydew-producing pests. Interestingly, they also protect some non-honeydew producing pests such as California red scales. Argentine and native gray ants are the most common ant species that aggressively protect pest insects. In addition, Argentine ants can plug up irrigation sprinklers.

Role of Chlorpyrifos: Lorsban is very effective in killing surface ants when sprayed on the ground or when granularly (not included in cost analysis) directed to the soil.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate to Severe
Damage	Disruption of biological control agents and plugging of irrigation lines
Frequent or Occasional Pest	Frequent
Distribution	Argentine ant is common in S. California and the coast and native gray ant common in the San Joaquin Valley.
Timing of Outbreaks	February –October

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Chlorpyrifos 1B	Lorsban Advanced (Low VOC)	1B	1	None noted
Chlorpyrifos	Lorsban 15G	1B	1	None noted

Alternative Management Practices

Practice	Comments
Skirt Pruning and sticky materials Cultivation, but dust can disrupt BC of other pests	Extremely labor intensive and impractical for commercial citrus and stickem can damage trees

Other Considerations and Knowledge Gaps

Research	Policy	Education
Need to develop liquid or gel bait stations that are effective in agriculture Study efficacy of Agri-Flex (Abamectin + Thiamethoxam) as a potential alternative Organic insecticide/baits needed.	None noted	Has effect on Argentine ants

Asian Citrus Psyllid
Diaphorina citri

Asian citrus psyllid attacks all varieties of citrus and very closely related ornamental plants in the family Rutaceae (mock orange, Indian curry leaf, orange jasmine, and other Murraya species). This pest attacks new citrus leaf growth and, because of the salivary toxin that it injects, causes the new leaf tips to twist or burn back.

However, the more serious damage that it causes is vectoring the bacterium (Candidatus Liberibacter asiaticus) that causes Huanglongbing (HLB or citrus greening) disease. Huanglongbing causes shoots to yellow, asymmetrical leaf mottling, and abnormally shaped fruit with bitter juice. The disease can kill a citrus tree within 3 to 5 years, and there is no known cure for the disease. Asian citrus psyllid arrived in southern California from Mexico in 2008.

At this point, Huanglongbing is rapidly spreading in Mexico northward toward California. In addition, Huanglongbing may already be present in California due to previous illegal importation of infected plant material. In Florida the psyllid and disease were rapidly spreading throughout the state on nursery plants such as Murraya. It is thought that Huanglongbing was present in Florida backyard citrus trees for a number of years, and it took the arrival of Asian citrus psyllid to move the disease into commercial citrus orchards. Florida citrus growers are now treating more than eight times per year with broad-spectrum pesticides to reduce Asian citrus psyllid and slow the spread of the disease. Pesticides can reduce the number of psyllids, but an adult psyllid carries the bacteria for most of its life and it only takes a few psyllids to spread the disease.

Currently, treatments that are applied to California citrus orchards are designed to disinfest trees and thus minimize the risk of moving Asian citrus psyllid in bins of harvested fruit and to limit the spread of Asian citrus psyllid and HLB throughout California.

Role of Chlorpyrifos: OPs are used in season for ACP control as part of a rotation of chemical classes, especially when needed for other pests. The organophosphates are an important tool in the late fall because they can be used close to harvest because they have well-established MRLs. Chlorpyrifos is one of many tools for managing psyllids with an important role when pests such as citricola scale, Fuller rose beetle, and citrus bud mite need control at the same time.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Severe
Damage	HLB disease vector; leaf tip burn
Frequent or Occasional Pest	Not recorded but major potential pest
Distribution	Primarily in S. California as of early 2014
Timing of Outbreaks	Spring through fall, whenever new flush is available

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Abamectin + Oil	Agri-Mek SC, ABBA 0.15 EC	6	NA	None noted
Beta-cyfluthrin	Baythroid	3A	0.31	Pyrethroids are most effective and used as first treatment for the eradication strategy and also useful in the cold winter months to kill overwintering adults
Beta-cyfluthrin Imidacloprid	Leverage Premix	Mixed 3A, 4a	0.43	None noted
Carbaryl	Sevin	1A	1.00	Lower efficacy
Chlorantraniliprole	Altacor	28	1.46	Lower efficacy
Chromobacterium subtsugae strain	Grandevo	UC	0.58	Primarily active against nymphs. Short residual. Organic acceptable.
Diflubenzuron	Micromite	15	0.51	Primarily active against nymphs
Dimethoate	Dimethoate	1B	0.30	None
Fenpropathrin	Danitol	3A	0.88	Pyrethroids are most effective and used as first treatment for the eradication strategy and also useful in the cold winter months to kill overwintering adults
Fenproximate	Fujimite	21A	1.31	None noted
Imidacloprid	Admire Pro and generics	4A	0.39	Soil application is critical for management of nymphs
Narrow Range Oil	415 Superior Oil	UC	4.24	Short residual, primarily a contact insecticide. Organic option
Pyrethrins	Pyganic		2.28	Short residual, primarily a contact insecticide, organic acceptable
Spinetoram	Delegate	5	1.86	None
Spinosad	Entrust	5	2.28	Short residual. Organic option
Spirotetramat	Movento	23	2.95	Primarily active against nymphs
Thiamethoxam	Actara	4A	0.55	None noted
Zeta-cypermethrin	Mustang	3A	0.51	Lower efficacy than other pyrethroids
Chlorpyrifos	Lorsban	1B	1.00	None noted

Alternative Management Practices

Overwintering adults and new flushes are best managed by applications to reduce populations early. Repeated use of one chemical class is discouraged to manage resistance. ACP-effective choices are encouraged when insecticide treatments are needed for other pests.

Other Considerations and Knowledge Gaps

Research	Policy	Education
Resistance management plans are under development ACP needs immediate action. Need for organic solutions. The role of chlorpyrifos for control of adult psyllids entering overwintering phase.	MRL establishment is a key issue because many new products are not registered in key markets.	Resistance management. ACP needs immediate action

Black Scale
Saissetia oleae

Black scale is a major citrus pest in southern California but occurs only occasionally on citrus in the San Joaquin Valley, mostly on grapefruit or on trees near olives. Feeding by black scale reduces tree vigor and can cause leaf or fruit drop and twig dieback. Excreted honeydew supports the growth of sooty mold.

In the coastal, intermediate, and interior districts, black scale is a cyclical pest that requires intervention every 5 to 10 years.

Role of Chlorpyrifos: When black scale occasionally becomes a problem, chlorpyrifos is a very good material to keep populations at low levels. Control by natural enemies is effective in managing black scale, however, if parasite activity is disrupted by ants, dust or pesticides, treatments may be necessary. Treatments also pick up California red scale.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate to High
Damage	Mainly loss of vigor to trees; poor bud development
Frequent or Occasional Pest	Occasional
Distribution	Mainly coastal and some inland
Timing of Outbreaks	Early in season (May – July); Treat early manage buildup of populations

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Carbaryl	Sevin	1A	1.94	None noted
Narrow Range Oil	Narrow Range Oil	UC	5.66	None noted
Spirotetramat	Movento	23	2.95	None noted
Chlorpyrifos	Lorsban	1B	1.00	None noted

Alternative Management Practices

Practice	Comments
Conservation of natural enemies Ant control	None noted

Other Considerations and Knowledge Gaps: None noted

Broad Mite
Polyphagotarsonemus latus

Broad mites feed on fruit and leaves, preferring young fruit up to about 1 inch (2.5 cm) in diameter that are located on the inside of the canopy or on the inward facing side of outer fruit. Feeding results in scarred tissue that cracks as fruit grows, leaving a characteristic pattern of scars and new tissue; and/or many fruit are completely scarred or scarred on the shady side of the fruit if the fruit is located on the outer sunny side of lemon trees. Although most feeding occurs on fruit, broad mites may also feed on young expanding leaves causing them to curl. This cupping and curling of leaves can appear similar to mild damage caused by glyphosate-Roundup applications.

Broad mites are occasional pests of coastal lemons from late July through early October; infestations are enhanced by the presence of Argentine ants. This mite often occurs in conjunction with Citrus Rust Mite/Silver Mite. Lorsban applied for citrus rust mite will pick up broad mite.

Populations of broad mite tend to be most severe in warm, humid conditions such as found in greenhouses. No treatment thresholds have been developed for broad mite in citrus. If high and increasing populations warrant treatment, use miticides with the least toxicity to predaceous mites.

Ants drive mealybugs which drive broad mite populations. Managing ant populations is very important when broad mites are a concern.

Role of Chlorpyrifos: Chlorpyrifos is one of several active ingredients used for Broad Mite. While it is not the primary choice for control, it is useful when additional pests are present. It is the least disruptive to natural enemies as compared to other registered products.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate to severe
Damage	Leaf curl and fruit scarring Mainly fruit scarring
Frequent or Occasional Pest	Occasional
Distribution	Primarily a coastal pest; control approaches and efficacy of control measures vary by geography
Timing of Outbreaks	After bloom and when fruit are small

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Abamectin + Oil	Agiri-Mek, and generics such as ABBA (many generics)	6	NA	Industry standard, VOC issue with generics ; question about efficacy
Fenproximate	Fujimite	21A	5.64	Effective, but need research on residuality
Sulfur, Wettable	Sulfur wettable powder	UC	0.11	Organic standard
Spirodiclofen	Envidor	23	NA	None noted
Chlorpyrifos	Lorsban	1B	1.00	None noted

Alternative Management Practices

Practice	Comments
Conservation of natural enemies	Expertise in organic management lacking
Ant control	

Other Considerations and Knowledge Gaps

Research	Policy	Education
Need data on residual efficacy of Envidor (Spiroclofiden)	None noted	None noted

California Red Scale

Aonidiella aurantii

California red scales attack all aerial parts of the tree including twigs, leaves, branches, and fruit by sucking on the plant tissues with their long, filamentous mouthparts. Heavily infested fruit may be downgraded in the packinghouse; and, if population levels are high, serious damage can occur to trees. Severe infestations cause leaf yellowing and drop, dieback of twigs and limbs, and occasionally death of the tree. Tree damage is most likely to occur in late summer and early fall when scale populations are highest and moisture stress on the tree is greatest.

Management of California red scale varies according to location in the state and the other pests present in the orchard. Natural enemies can provide good control of California red scale in all regions of California except the Coachella Valley where it is under pesticide eradication. However, biological control tends to be easiest in the coastal areas and some inland districts of southern California because milder weather in these regions allows the overlap of generations, which provides susceptible host stages for parasitism year round.

Tree damage is most likely to occur in late summer and early fall when scale populations are highest and moisture stress on the tree is greatest.

Role of Chlorpyrifos: Best use is in situations where multiple pests are present, such as when California red scale and citricola scale are present at the same time, so that multiple pests are controlled with one insecticide treatment.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate to Severe
Damage	Damage to twigs, leaves, branches, and fruit; occasional tree die off
Frequent or Occasional Pest	Frequent
Distribution	Statewide
Timing of Outbreaks	Slow build-up peaking in the Fall and affecting fruit when it is harvested

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Buprofezin	Applaud	16	7.67	lower efficacy than pyriproxyfen
Carbaryl	Sevin	1A	1.09	None noted
Methidathion	Supracide	1B	2.22	None noted
Narrow Range Oil	415 Superior Oil	UC	2.55	Organic option; less effective
Pyriproxyfen	Esteem	7C	2.48	Detrimental to Vedalia beetle if applied early in the season.
Spirotetramat	Movento	23	1.48	Major MRL issues Effective; may be more economical in certain areas due to less spray volume required; safer for bees but not allowed during bloom except on the coast
Chlorpyrifos	Lorsban	1B	1.00	None noted

Alternative Management Practices

Practice	Comments
Conservation of natural enemies	A complex of Aphytis, Comperiella, beetles and lacewings work together to provide control of CRS
Ant control	None noted
Biological control	Excellent if ants controlled
Pruning, Internal, & Skirt Treatments	Effective; Regulatory issues with trading partners are driving use of these practices
Dust reduction	None noted

Other Considerations and Knowledge Gaps

Research	Policy	Education
None noted	MRL establishment is a key issue because many new products are not registered in key markets Chlorpyrifos needed in desert region for eradication program	Most alternatives are more bee friendly

Citricola Scale
Coccus pseudomagnolarium

Citricola scale is one of the most serious pests of citrus in the San Joaquin Valley. A severe infestation may reduce tree vigor, kill twigs, and reduce flowering and fruit set. As they feed, citricola scale excretes honeydew, which accumulates on leaves and fruit. Sooty mold grows on honeydew and interferes with photosynthesis in leaves and causes fruit to be downgraded in quality during packing. The most important damage that it causes is significant loss of fruit yield when populations are high. Citricola scale is more difficult to control than California red scale and is considered a driver of broad-spectrum pesticide use where present. It also drives use of neonicotinoids which are very disruptive to natural enemies which are already lacking in the San Joaquin Valley. No selective insecticides are available.

Role of Chlorpyrifos: Some populations in the San Joaquin Valley have resistance to chlorpyrifos; others do not. Best use is in situations where multiple pests are present, such as California red scale and citricola scale, so that multiple pests are controlled with one insecticide treatment.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Severe
Damage	Reduction in tree vigor, flowering and fruit set; soot on fruit reduces quality
Frequent or Occasional Pest	Frequent
Distribution	San Joaquin Valley only
Timing of Outbreaks	Spray when adults are full size and in August/September when there is a new hatch

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Acetamiprid	Assail	4A	2.12	None noted
Buprofezin	Applaud	16	NA	Less effective
Carbaryl	Sevin	1A	1.93	Less effective
Imidacloprid	Admire Pro	4A	2.01	Suppressive
Malathion	Malathion	1B	2.34	None noted
Methidathion	Supracide	1B	4.94	None noted
Narrow Range Oil	Narrow Range Oil	UC	5.66	Organic option, weakly effective, requires multiple applications
Chlorpyrifos	Lorsban	1B	1.00	None noted

Alternative Management Practices

Practice	Comments
Pruning to improve spray coverage	None noted
Ant control	

Other Considerations and Knowledge Gaps

Research	Policy	Education
Effective Organic products Effective natural enemies	MRL establishment is a key issue because many new products are not registered in key markets . Alternatives to control both Citricola and CRS Citricola is why chlorpyrifos is used for CRS	None Noted

Citrus Bud Mite

Eriophyes sheldoni

Citrus bud mite is primarily a pest of coastal lemons but in recent years has also been found in interior regions of southern California. Bud mite has always been there; it just wasn't treated. The mites feed inside the buds, killing them or causing a rosettelike growth of the subsequent foliage and distortion of flowers and fruit, which may or may not reduce yield, fruit quality, or both.

Role of Chlorpyrifos: Chlorpyrifos is one of several active ingredients used for citrus bud mite. While it is not the primary choice for control, it is useful when additional pests are present. Chlorpyrifos is used as a "clean up" material for bud mite. Applications are typically made in the fall.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Slight to Moderate
Damage	Bud feeding may reduce yield (of first grade fruit) and/or fruit quality
Frequent or Occasional Pest	Occasional to frequent
Distribution	Primarily coastal but expanding into interior regions but has always been there (Corona)
Timing of Outbreaks	Bloom (note – in coastal region, citrus is continually in bloom)

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Abamectin	Agri-Mek, generics	6	NA	None noted
Fenbutatin Oxide	Vendex	12B	1.19	None noted
Narrow Range Oil	Narrow Range Oil	UC	5.66	Dilute oils are used in organic and conventional orchards
Chlorpyrifos	Lorsban	1B	1.00	None noted

Alternative Management Practices: None noted

Other Considerations and Knowledge Gaps: None noted
Develop data to evaluate and compare use of abamectin and chlorpyrifos for bud mite

Citrus Leafminer

Phyllocnistis citrella

Citrus leafminer larvae feed by creating shallow tunnels, referred to as mines, in young leaves. It attacks all varieties of citrus. The larvae mine the lower or upper surface of the leaves causing them to curl and look distorted. Mature citrus trees (more than 4 years old) generally tolerate leaf damage without any effect on tree growth or fruit yield. Citrus leafminer causes damage in nurseries and new plantings because the growth of young trees is retarded by leafminer infestations; and in the case of nurseries, trees shipped to other states must be free of pests. However, even when infestations of citrus leafminer are heavy on young trees, trees are unlikely to die.

Role of Chlorpyrifos: One of a group of treatments rotated for protecting young citrus trees. Foliar insecticides only last until the next flush and so frequent treatments are needed for this pest. Currently chlorpyrifos is not labeled for this target.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate to Severe
Damage	Direct damage to leaves resulting in stunting of young trees up to six years old
Frequent or Occasional Pest	Frequent pest of young trees in nurseries and in the field
Distribution	Statewide
Timing of Outbreaks	Worst in summer and fall

Alternative Active Ingredients (AI) : Currently chlorpyrifos is not labeled for this target.

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Abamectin + Oil	Agri-Mek SC, ABBA 0.15 EC	6	NA	None noted
Azadarachtin	Neemazid	UC	NA	None noted
Buprofezin	Applaud	16	NA	None noted
Chlorantraniliprole	Altacor	28	NA	Lower efficacy
			NA	
Diflubenzuron	Micromite	15	NA	None noted
Imidacloprid	Admire Pro	4A	NA	None noted
Narrow Range Oil	415 Superior Oil	UC	NA	Short residual, primarily a contact insecticide. Organic option
Spirotetramat	Movento	23	NA	None noted
Thiamethoxam	Actara	4A	NA	None noted

Other Considerations and Knowledge Gaps

Research	Policy	Education
Importation of parasitoids is needed for biocontrol to be successful	None Noted	None Noted

Citrus Rust Mite (Silver Mite)

Phyllocoptruta oleivora

This pest is known as the rust mite on oranges and the silver mite on lemons. It is an occasional pest in coastal areas of southern California and is a problem in some years in inland southern California growing areas.

The rust mite feeds on the outside exposed surface of fruit that is 0.5 inch (1.3 cm) or larger. Feeding destroys rind cells and the surface becomes silvery on lemons, rust brown on mature oranges, or black on green oranges. Rust mite damage is similar to broad mite damage, except that somewhat larger fruit are affected. Most rust mite damage occurs from late spring to late summer.

Role of Chlorpyrifos: Apply this material in Sept.-Oct. only if several pests, such as citrus bud mite, citrus thrips, and ants, need to be controlled in addition to citrus bud mite (PMG).

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate to Severe
Damage	Fruit rind feeding reduces quality
Frequent or Occasional Pest	Occasional
Distribution	Coastal and inland Southern areas
Timing of Outbreaks	Varies

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Abamectin	Agiri-Mek, and generics such as ABBA	6	NA	None noted
Diflubenzuron	Micromite	15	0.57	None noted
Fenproximate	Fujimite	21A	3.13	None noted
Spirotetramat	Movento	23	2.95	None noted
Spirodiclofen	Envidor	23	NA	None noted
Sulfur, (Micronized, wettable)	Sulfur - micronized WP	UC	0.66	Effective but disruptive to natural enemies
Sulfur, Wettable	Sulfur wettable powder	UC	1.62	None noted
Chlorpyrifos	Lorsban	1B	1.00	None noted

Other Considerations and Knowledge Gaps: None noted

Earwigs
Forficula auicularia

The introduced European earwig (family: Forficulidae) is the most damaging earwig species that can occur in citrus. Earwigs feed on dead and living insects and insect eggs, other organisms, and on succulent plant parts. Earwigs occasionally damage buds and leaves on young or newly grafted trees and fruit on mature trees just after petal fall. They can be especially problematic on trees with trunk wraps or cardboard guards.

The cause of damage can be difficult to distinguish from that of other chewing pests that hide during day and feed at night, including brown garden snail and Fuller rose beetle.

Role of Chlorpyrifos: Lorsban is very effective when sprayed inside the wraps of young trees or on the foliage of mature trees. Earwigs are very difficult to kill with products other than OPs, carbamates, and pyrethroids. Currently chlorpyrifos is not labeled for this target.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate to Severe
Damage	Feeding on leaves and fruit
Frequent or Occasional Pest	Occasional
Distribution	Statewide
Timing of Outbreaks	At bloom in Springtime

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
None noted	None noted		None noted	None noted

Alternative Management Practices

Practice	Comments
Remove trunk wraps promptly	None noted

Other Considerations and Knowledge Gaps

Research	Policy	Education
Effective baits needed	None noted	None noted

Fuller Rose Beetle

Naupactus (Asynonychus) godmani

The beetle itself does not cause economic damage in California citrus but the presence of viable eggs on fruit exported to other countries such as Korea can be a quarantine concern. Since Fuller rose beetle has been found in Japanese citrus groves, it is no longer a concern for fruit exported to Japan.

Fuller rose beetle adults feed along the margins of citrus leaves, creating notches, and leaving a characteristic sharp, ragged appearance. The larvae live in the ground and feed on tree roots. In California, Fuller rose beetles is not a concern except on topworked trees where the beetles will feed on new buds or if a young tree is planted in a mature grove and beetles concentrate their feeding on the new growth of that tree. In California FRB is not considered an economic pest. However, it lays its eggs in under the calyx of citrus fruit. Korea has declared FRB a high risk pest. If citrus fruit arrives in Korea infested with FRB eggs, the fruit loads are rejected, causing severe losses for the growers.

If management of Fuller rose beetles is necessary because it has become a quarantine concern, there are two management strategies that incorporate cultural and chemical control methods: season-long local suppression and treatments to prevent egg laying close to harvest. The beetles are flightless and so skirt pruning and trunk treatments limit their access to fruit to climbing up the trunk. Trunk, ground and/or foliar sprays help to limit or eliminate the beetles from the trees.

Role of Chlorpyrifos: One treatment choice for in-season control of the beetles to help prevent them from laying eggs on fruit. Chlorpyrifos controls other pests simultaneously, such as citricola scale and California red scale and it has long-established MRLs.

Pest Status

Attribute	Status
New or Established Pest	Severe issue for export markets
Potential for Severity/ Economic Loss	Damage to leaves, irrigation equipment, quarantine issue
Damage	Frequent
Frequent or Occasional Pest	Statewide but mainly San Joaquin Valley
Distribution	Moderate to severe, especially navels
Timing of Outbreaks	Severe issue for export markets

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Beta-cyfluthrin	Baythroid	3A	0.23	Product limited in availability
Bifenthrin	Brigade	3A	2.90	Applied to the ground or trunk only. Can not have residues reach fruit.
Carbaryl	Sevin	1A	0.22	MRL issues
Cryolite	Kryocide	UC	2.10	No MRLs established
Thiamethoxam	Actara	4A	0.77	None noted
Imidacloprid + beta cyfluthrin	Leverage	Premix 3A, 4A	0.67	None noted
Thiamethoxam + chlorantraniliprole	Voliam Flexi	Premix 4A, 28	NA	None noted
Chlorpyrifos	Lorsban	1B	1.00	None noted

Alternative Management Practices

Practice	Comments
Skirt pruning	None noted
Sticky materials to prevent access to canopy	Extremely labor intensive and impractical for commercial citrus

Other Considerations and Knowledge Gaps

Research	Policy	Education
Post harvest fumigation research is underway	Methyl Bromide replacements MRL establishment is a key issue because many new products are not registered in key markets	None noted

Katydids

Scudderia furcata

Forktailed katydid is the only species that causes economic damage. It feeds on the rind of young fruit at petal fall with subsequent buildup of scar tissue and distortion of expanding fruit. Katydids take a single bite from a fruit and then move to another feeding site on the same or nearby fruit. In this way, a few katydids can damage a large quantity of fruit in a short time.

Role of Chlorpyrifos: Katydids are easily killed by very low rates of chlorpyrifos at petal fall. Chlorpyrifos is very effective and is not as disruptive as other materials because many natural enemies have resistance to chlorpyrifos (predatory mites, parasitic wasps and predatory beetles).

Pest Status

Attribute	Status
Potential for Severity/ Economic Loss	High
Damage	Leaf feeding, fruit scarring
Frequent or Occasional Pest	Frequent
Distribution	San Joaquin Valley
Timing of Outbreaks	Bloom to fruit enlargement

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Beta-cyfluthrin	Baythroid	3A	0.55	Very low rates are effective
Cryolite	Kryocide	UC	1.64	Slow acting stomach poison
Diflubenzuron	Micromite	15	0.43	Slow acting insect growth regulator
Dimethoate	Dimethoate	1B	0.27	None noted
Fenpropathrin	Danitol	3A	1.33	None noted
Naled	Dibrom	1B	0.86	None noted
Chlorpyrifos	Lorsban	1B	1.00	None noted

Other Considerations and Knowledge Gaps: None noted

Mealybugs

Citrus mealybug: *Planococcus citri*
Citrophilus mealybug: *Pseudococcus calceolariae*
Longtailed mealybug: *Pseudococcus longispinus*
Comstock mealybug: *Pseudococcus comstocki*

Mealybugs extract plant sap, reducing tree vigor, and excrete honeydew, which gets on plant surfaces and provides a surface upon which sooty mold grows. If a cluster of mealybugs feeds along a fruit stem, fruit drop can occur. Damage is most severe in spring and fall.

The role of mealybugs in citrus IPM is pivotal to other pest issues. Ants protect mealy bugs from natural enemies which can require insecticides which reduce predatory mites, causing outbreaks of mites (e.g., broad mite).

Role of Chlorpyrifos: Chlorpyrifos is one of very few insecticides available and it is not as disruptive to natural enemies because the predatory beetles have developed resistance to it.

Pest Status

Attribute	Status
Potential for Severity/ Economic Loss	Moderate to High
Damage	Direct feeding and production of sooty mold
Frequent or Occasional Pest	Occasional
Distribution	S. California
Timing of Outbreaks	Slow building populations; best to treat early

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Chlorpyrifos	Lorsban	1B	1	None noted
Spirotetramat	Movento	23	2.95	None noted

Alternative Management Practices

Practice	Comments
Release of *Crytolaemus* (Mealy bug destroyer) is the primary natural control.	This is the primary control

Other Considerations and Knowledge Gaps: None noted

Cotton Crop Team Report

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Overview

Through a facilitated process, the Cotton Crop Team identified ten insect pests for which chlorpyrifos was important and required continued access to it. Of these pests, cotton aphid and sweetpotato whitefly (Biotype B) required annual use of this active ingredient to protect cotton lint and preserve the producers' reputation and marketplaces for high quality cotton. IPM practices are widely used throughout California including sampling pest populations, assessing the threat and choosing selective and/or reduced risk insecticides when available. The industry depends on cultural controls and conservation of natural enemies as alternative management approaches to insecticide use. Practices which mitigate risks from chlorpyrifos use are utilized.

Figure 5.1. Cotton production areas in California.

Introduction and Background

In 2013, California produced 898,067 bales of cotton lint from 279,012 acres of land, averaging 3.22 bales per acre and valued at $623,242,000. In addition to cotton lint, the cottonseed is utilized for oil and livestock feed and valued at $135,044,000. There are several areas in California in which cotton is produced but 95% is produced in the San Joaquin Valley, with the remainder in southeastern California and a small acreage in the Sacramento Valley (Figure 5.1). Two species of cotton are produced California, Acala upland *(Gossypium hirsutum)* and Pima *(G. barbadense)*.These cottons are high quality and go into high end threads and fabrics. Ninety to 100% of California cotton is exported, primarily to the Far East.

Cotton is a perennial plant grown as an annual crop. In the San Joaquin Valley, planting and crop destruction dates are set to provide a host free period and to prevent pink bollworm from establishing. Planting can begin in mid-March but scheduling is based on temperature forecasts, which promote early seedling vigor and strong plant development. Harvest of cotton occurs between September and November and is preceded by defoliation of the plant and preparing it for mechanical harvest.

Cotton Integrated Pest Management (IPM)

Cotton has a long history in developing IPM systems. It was one crop identified in the Huffaker IPM Project in the 1970's as a potential candidate to improve the judicious use of pesticides. Cotton was identified as one of the seven initial crops on which the UC Statewide IPM Program would focus. IPM practices have been widely adopted over the last several decades.[1]

Cotton Production in California

- 279,000 acres
- 753,000 Million dollars
- 3.2 bales/acre

There is a wide diversity of pests which affect quantity (yield) as well as quality of California cotton (Figure 5.2). Lygus, pink bollworm, armyworms, other caterpillar pests and stink bugs can directly reduce yield by attacking buds, flowers and fruit directly. Yield loss can occur indirectly through stand decline caused by thrips, and soil insects (seedcorn maggot, wireworm), leaf feeding (worms and caterpillars), loss of chlorophyll (spider mites, leafhopper) or directly feeding plant vascular system (aphid and whitefly).

Of these pests, Lygus, spider mites, aphids, and whiteflies appear annually in many fields in California. Lygus, aphids, and whiteflies are key pests in cotton's IPM system. Lygus is key because how and when it is managed can impact the presence and abundance of natural enemies in the cotton ecosystem for the entire season as well as the yield losses which can result from Lygus bug infestations. Whiteflies and aphids are key pests because of the threat they present late in the season when it is difficult to get coverage and lint is susceptible to honeydew. Rarely is only one pest present; and depending on the year and location, a complex of diverse arthropod pests may require attention simultaneously.

[1] Brodt, S.B., P.B. Goodell, R.L. Krebil-Prather and R.N. Vargas. 2007. California cotton growers utilize integrated pest management. California Agriculture:16:1:24-30

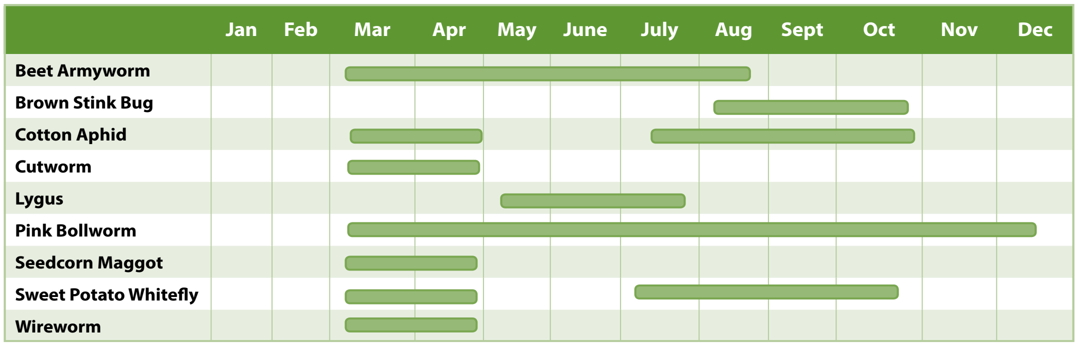

Figure 5.2. Seasonality of important cotton pests. Actual presence and duration of a pest will vary by production region.

In order to command high prices, lint quality characteristics must be maintained, which include length, strength, and fineness. In addition, the product must be free from contaminants,

including leaf and stem trash, foreign material, and insect sugars. Of the dozen key pests that attack California cotton, cotton aphid and sweetpotato whitefly (Biotype B) are of primary concern for quality concerns. Late season feeding results in excrement (honeydew) falling onto exposed lint, creating spinning and process problems. Developing a reputation as a source of sticky cotton will destroy a region's ability to market high value cotton. The threat from aphid and whitefly drives late season pest management decisions. In rare cases, fields have been abandoned due to the overwhelming damage caused by whitefly or harvested cotton cannot be processed and/or marketed due to the levels of insect honeydew. Details of seasonal occurrence and management of these insect pests can be found in the Year Round IPM Program at UC IPM Pest Management Guidelines.[2]

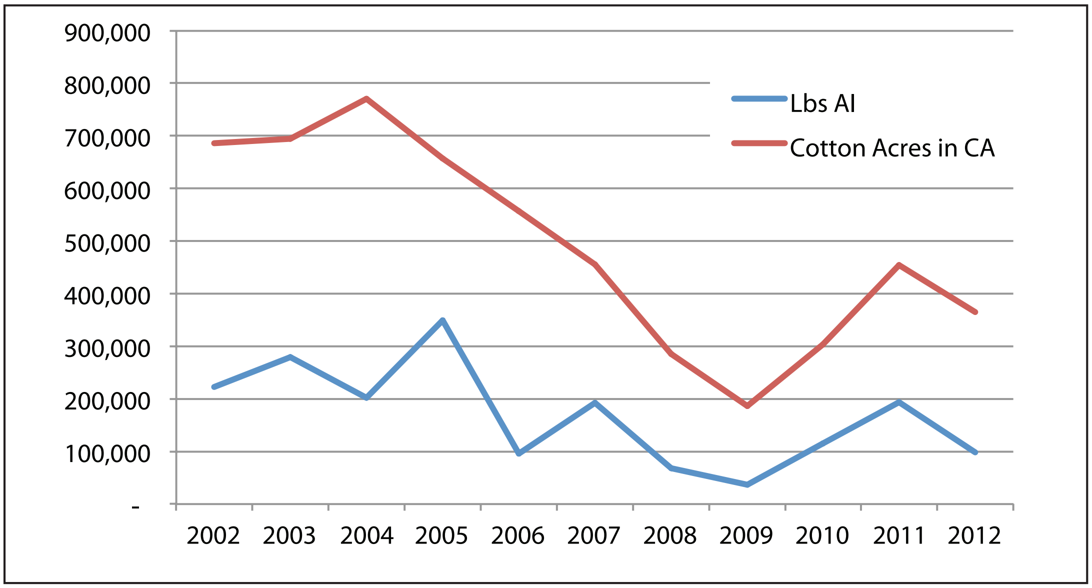

Figure 5.3. Pounds of chlorpyrifos and acres of cotton planted in California (2002-2012).

[2] *www.ipm.ucanr.edu*

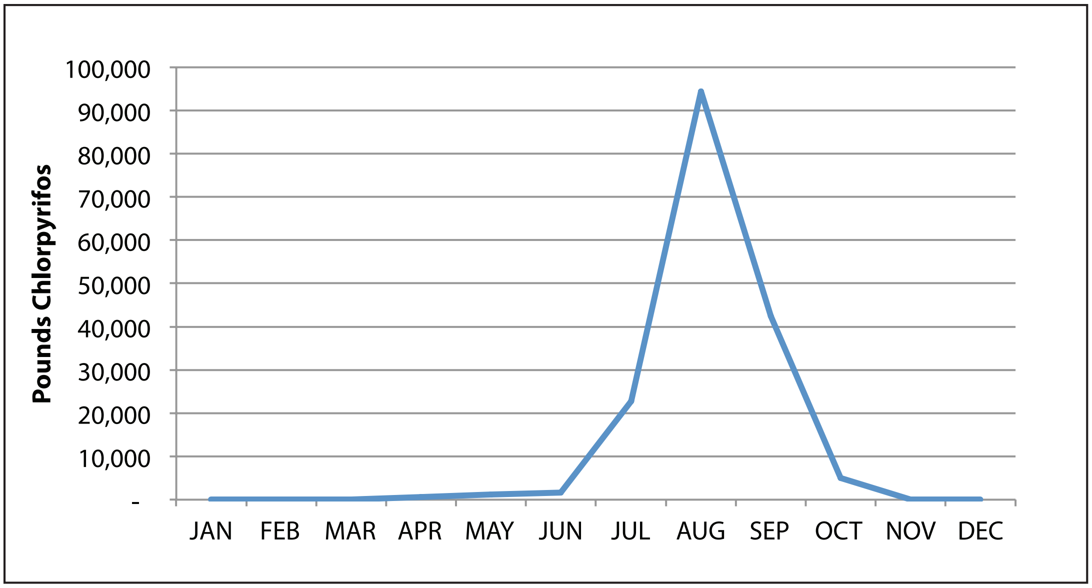

Figure 5.4. Chlorpyrifos use in cotton by month (2002-2012).

Criticality of Chlorpyrifos in Cotton IPM

Chlorpyrifos is one of many active ingredients (Appendix 6) on which pest managers and growers rely. During the process of identifying critical uses, ten insect pests were identified (Table 5.1). Of these, two were considered **Key** with no or few alternative products, three were considered **Important** but alternative active ingredients were available, and five were considered **Occasional** pests with alternative active ingredients available. In addition to the number of insecticide alternatives available, the number of alternative practices available was an important consideration. These are listed for each pest in the Pest Profiles section with practices including cultural (host plant resistance, area wide mating disruption) and biological controls (conservation of natural enemies).

Critical Uses of Chlorpyrifos in Cotton

Criticality Tier	Pest	Number of Modes of Action in Addition to Chlorpyrifos	Alternative Practices Available
Key Pests with Few or No Alternatives	Cotton Aphid (Late Season)	0	No
	SweetpotatoWhitefly (Late Season)	2	Limited
Important Pests with Alternatives	Brown Stinkbug	Unknown	Limited
	Cotton Aphid (Early to Mid Season)	5	No
	Lygus	6	Limited
Occasional Pests with Alternatives	Cutworms	2	No
	Beet Armyworm	5	Yes
	Pink Bollworm	3	Yes
	Seedcorn Maggot	1	No
	Wireworms	0	No

Table 5.1. Critical uses of chlorpyrifos in cotton. Modes of action refer to the Insecticide Resistance Action Committee (IRAC) classification (www.irac-on-line.org.)

Chlorpyrifos Use Pattern

Chlorpyrifos was applied to 36% of the cotton acres between 2002-2012 (Appendix 11). On average during this period, 0.91 lbs. of AI was applied to each treated acre. Of the chlorpyrifos usage, 89% was applied by air and 11% by ground (CDPR PUR data). During the period 2002-2012, total pounds of chlorpyrifos use peaked in 2005 and then declined (Figure 5.3). An increase in use over the past several years can be related to increased whitefly presence in the San Joaquin Valley caused by late season migrations of adults into cotton fields and is reflected in the monthly use summary (Figure 5.4). During this period when lint is exposed to insect sugars, the tactic is to reduce adult whiteflies before they feed and excrete honeydew, using broad spectrum insecticide combinations, including chlorpyrifos.

"Over the past dozen years, it seems like we have been playing a game of Jenga® with CDPR; they have pulled one AI after another until we depend on an important product to hold up the pest management system"

The Cotton Crop Team emphasized the importance of chlorpyrifos in cotton pest managing pests in cotton. They note that the loss of other active ingredients has placed more importance on chlorpyrifos and driven its increased use. Examples the team provided included carbofuran, endosulfan, aldicarb, and methamidophos.

Relative Cost of Alternate AIs to Chlorpyrifos

The cost of alternative active ingredients relative to chlorpyrifos depended on cost per unit of product and the recommended rates per acre. Table 5.2 presents the relative costs of alternative AIs to chlorpyrifos for control of cotton pests. The range of relative costs varied between a low of 0.27 of the cost of chlorpyrifos to a high of 5.68. Details of alternative active ingredients and practices can be viewed individually in the Pest Profiles section.

Brown stinkbug is a new pest in California, and the optimum control strategy has yet to be developed. Based on experience and research in others states, the primary active ingredients will be older chemistry. In the early season, some soil insect pests did not have a label for chlorpyrifos, except cutworms.

Tier	Pest	Low	High	Comments
1	Cotton Aphid Late Season	0.87	4.58	Chlorpyrifos is only AI which has efficacy and plant canopy penetration
	Whitefly, Late Season	0.55	2.15	Tank mixes including chlorpyrifos required to control adults
2	Cotton Aphid, Early to Mid-Season	0.28	3.42	Alternative selective products available, application more reliable into smaller plant canopy
	Brown Stink Bug	NA	NA	New pest, control is being developed
	Lygus	0.34	2.34	If present when other pests require treatment, chlorpyrifos provides more broad spectrum control
3	Cutworm	1.19	2.08	Alternative materials available
	Pink Bollworm	0.27	3.36	Rarely used, pest nearly eradicated, has been important when multiple pests present
	Beet Armyworm	0.04	5.68	Selective alternative AIs available
	Seedcorn Maggot	NA	NA	Chlorpyrifos not labeled for pest
	Wireworms	NA	NA	Chlorpyrifos not labeled for pest
	Summary	**0.04**	**5.68**	

Table 5.2. Relative costs of alternative AIs compared to chlorpyrifos products in cotton. If the average cost per acre is equal to the price of chlorpyrifos, the value would be 1.0.

Gaps in Research, Extension and Policy

The Crop Team identified the following research, extension and policy needs relative to chlorpyrifos use. These are in no particular order.

Research Needs

- *Evaluate efficacy of alternative AIs*

- *Develop a program to monitor insecticide resistance in key pests*

- *Enhance development and research effort by crop protection industry for new insecticide chemistries to augment existing tools*

- *Manufacturers need to create resistant varieties for the California cotton market*

- *Initiate research to evaluate transgenic cotton for Lygus management to predict the impact on insecticide use patterns*

- *Conduct research on new approaches to pesticide application*

- *Evaluate which insecticides could be delivered via buried drip line*

- *Conduct research to review, revise and augment sampling and decision making protocol for whitefly*

- *Develop basic information on pest biology*

- *Use improved pest biology information to refine ecosystem-based pest management programs.*

Extension Needs

The University of California has had strong cotton extension education program utilizing a diversity of outreach methods including presentations at production meetings, web pages (UC IPM guidelines and cotton websites), books (Cotton IPM manual, production manual), one page factsheets, in-depth workshops, field days, and blogs. Information specific to chlorpyrifos can be readily incorporated into these outreach programs and products. A full list of resources is provided in Resource and Reference section. Specific future outreach activities or objectives related to chlorpyrifos stewardship:

- *Improve information sharing about efficacy between manufacturers, the university, growers, and PCAs to make results more available , especially in keeping PMG current*

- *Conduct annual extension insect review meetings to share information on the situation of AIs and pest pressure*

- *Improve communication between PCAs and distributor to ensure availability of alternative active ingredients*

- *Better coordination between public agencies who annually monitor various insects on public land (e.g., rangeland and BLM propery) and extension to improve prediction of pest movement*

- *Better information sharing between PCAs, growers and extension to track regional outbreaks*

> *"How could we work better together to develop a strategic direction that incorporates the need for a robust insecticide tool box, yet reduce risks to human and environmental health? "*

Policy Needs

Manufacturer and Distribution Chain
- Provide consistent availability of effective AIs

- Evaluate the advantages and risks in packaging pre-mixes (a product with two AIs already in the package)

California DPR
- Improve the registration process which is slow, discouraging registrants in providing new AIs and slowing the rate of change to newer, selective products

California DPR and US EPA
- Reconsider factors leading to use Section 18 critical use exemption beyond just economics and to include implications of additional AIs on improving IPM

- Evaluate benefits of adding the Target Pest to the items being reported in the PUR system to be able to better track insecticide use

University of California
- Review value of increasing number of cotton research entomologists

- Review the value of providing an independent IPM funding source to respond to current and future IPM challenges

Potential Funding Sources for Cotton IPM

The Cotton Crop Team identified potential sources of funding to support research and outreach projects related to chlorpyrifos use in IPM systems.

Source	Organization and/or Program
Commodity	California Cotton Alliance California Cotton Growers and Ginners Associations Cotton Incorporated
State	CA Department of Pesticide Regulation - Research grants and Pest Management Alliance Program California Department of Food and Agriculture
Federal	EPA USDA Crop Protection and Pest Management (CPPM) USDA Pest Management Alternatives (PMAP) USDA Integrated Organic Program (IOM) USDA National Extension Integrated Pest Management Projects Program (EIPM) USDA Sustainable Agriculture Research and Education (SARE)
Regional	Western Region IPM Center - Work Groups and Pest Management Strategic Plans
Corporate	Pesticide manufacturers, seed companies and large farming organizations

Best Management Practices to Mitigate Use of Chlorpyrifos in Cotton

When planning for possible chlorpyrifos applications in an IPM program, consult the UC IPM Guidelines and consider the following Best Management Practices. For additional information, refer to the "Resources" section at the end of this document.

Consider water management practices that reduce pesticide movement off-site.

- ☐ Install an irrigation recirculation or storage and reuse system.
- ☐ Use drip rather than sprinkler or flood irrigation.
- ☐ Manage water use through soil moisture and evapotranspiration (ET) monitoring
- ☐ Consider vegetative filter strips or ditches.
- ☐ Install sediment traps.
- ☐ Apply polyacrylamides irrigation systems to prevent off-site movement of sediments.
- ☐ Redesign inlets and outlets into tailwater ditches to reduce erosion.

Consider practices that reduce air quality problems.

- ☐ When possible, reduce volatile organic compound (VOC) emissions by decreasing the amount of pesticide applied, choosing low-emission management methods, and avoiding fumigants and emulsifiable concentrate (EC) formulations.
- ☐ Use the Department of Pesticide Regulation calculators to determine VOC emission rates from fumigant and non-fumigant pesticides.

Choose a pesticide from the UC IPM Cotton PMG for the target pest, considering:

- ☐ Impact on natural enemies and honey bees.
- ☐ Potential for water quality problems using the UC IPM WaterTox database.
- ☐ Impact on aquatic invertebrates.
- ☐ Chemical mode of action (based on efficacy, spectrum of activity, and pesticide resistance). Select alternative chemical or nonchemical treatments, especially when resistance risk is high.
- ☐ Endangered species that may be near your site.

Before an application

- ☐ Ensure that spray equipment is properly calibrated to deliver the desired pesticide amount for optimal coverage.
- ☐ Minimize off-site movement of pesticides
- ☐ Use appropriate spray nozzles and pressure.
- ☐ Avoid spraying during conditions conducive to drift or runoff.
- ☐ Identify and take special care to protect sensitive areas surrounding the application site.
- ☐ Review and follow labeling for pesticide handling, personal protection equipment (PPE) requirements, storage, and disposal guidelines.
- ☐ Check and follow restricted entry intervals (REI) and preharvest intervals (PHI).

After an application

- ☐ Record application date, product used, rate, and location of application.
- ☐ Follow up to confirm that treatment was effective.

Consider practices that reduce air quality problems.

- ☐ When possible, reduce volatile organic compound (VOC) emissions by decreasing the amount of pesticide applied, choosing low-emission management methods, and avoiding fumigants and emulsifiable concentrate (EC) formulations.
- ☐ Use the Department of Pesticide Regulation calculators to determine VOC emission rates from fumigant and nonfumigant pesticides.

For more information, see UC IPM's Mitigating Pesticide Hazards (http://www.ipm.ucdavis.edu/mitigation/index.html)

Pest Profiles

As a part of the critical use discussions, the Cotton Crop Team identified a list of important pests for which chlorpyrifos is considered an important pest management tool.

In order to characterize these pests, general information on the role of this product in IPM, damage, seasonality, frequency and severity of pest outbreaks has been summarized for each species. In addition, cost and effectiveness of alternative products or best management practices for each pest were assembled in order to have a basis for evaluation and comparison.

This information has been formatted into a standardized format simply to describe the role of chlorpyrifos in IPM for the purpose of this project. For detailed information on pest biology, damage and pesticide usage, references to the UC IPM Guidelines and CDPR Pesticide Use Report are recommended.

The following section presents the pests identified by the Cotton Crop Team. The pests are presented in order of the criticality ranking determined by the team.

Cotton Aphid - Late Season

Aphis gossypii

This sucking insect taps into the phloem, extracts the sap, removes nitrogenous compounds, and excretes concentrated sugary fluids. Honeydew deposited on the lint can cause "sticky cotton" which results in severe reduction in quality and potential loss of market. The economic risk to cotton growers posed by "sticky cotton" is extreme. If a region is associated with this problem by spinning mills, future sales can be eliminated or discounts applied. Preserving the integrity of the cotton quality is paramount to cotton production.

Role of Chlorpyrifos: Chlorpyrifos is an important IPM component later in the season when lint is exposed. Chlorpyrifos is the best choice for effective late season aphid control since neonicotinoid products require translaminar movement and do not work well once cotton leaves develop a waxy layer or are covered in dust. Loss of older chemicals (organophosphates, carbamates, organochlorines) drives chlorpyrifos use.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Greatest threat is late season; reduction of quality, sticky cotton due to aphid excrement on lint, loss of market
Damage	Leaf cupping, stunting, contamination of lint
Regionality	Mostly SJV issue
Frequent or Occasional	Occasional but never allowed to build to threatening population
Timing of Outbreaks	Late season

Alternative Active Ingredients - No efficacious alternatives

Alternative Management Practices

Practice	Comments
Plant and harvest as early as practicable	Dependent on seasonal weather conditions
Avoid late irrigation & fertilization	Aphids prefer cotton plants that are well watered and highly fertilized. Thus avoid excessive or poorly scheduled nitrogen applications and irrigation events that stimulate growth later in the cropping season; match the nitrogen and irrigation use with the needs of the plant to produce optimal yield
Defoliate as effectively as possible, watch for buildup between defoliation and harvest	Avoid end of season migrations
Conserve natural enemies	Avoid the use of broad spectrum materials during early and mid-season
Cultivar selection	Pima cultivars appear to be more susceptible to aphid infestations and associated damage. Within the Acala cotton cultivars, hairy-leaf varieties, which comprise the majority of the market, are more susceptible to aphids than are smooth-leaf varieties. Not known what the pest pressure is when selecting cultivar so selection more about other factors rather than pest management
Propagate and add habitat for natural enemies	Some growers are using a mixture of plants along the edge of cotton fields to provide shelter, nutrition and prey for natural enemies.

Other Considerations and Knowledge Gaps

Research	Policy	Education
Aphid and resistant varieties, transgenic options Is planting date really effective at aphid control? Are there any new pesticide products to address aphids? Late season mitigation of sticky cotton, e.g. are overhead irrigation practices, effective in removing sugars?	Additional PUR information would be useful in understanding chlorpyrifos use patterns,.e.g. target species Removal of registrations for older chemical AIs (organophosphates, carbamates, organochlorines) is driving chlorpyrifos use.	Is the current monitoring and decision making protocol well understood?

Sweetpotato Whitefly (Silverleaf Whitefly)

Bemesia tabaci (Biotype B)

Whiteflies are sucking insects and their feeding removes nutrients from the plant. Feeding by high populations may result in stunting, poor growth, defoliation, boll shed, and reduced yields. As they feed, whiteflies produce large quantities of honeydew which, if deposited on fibers, will reduce cotton quality and may interfere with picking, ginning, and spinning. Honeydew also supports the growth of black sooty molds that stain lint, lowering its quality.

Whiteflies are difficult to manage once their populations have reached high levels. Repeated exposure to insecticide treatments is very likely to lead to development of resistant strains, as has occurred in the recent past. In general, the best approach is an integrated pest management strategy that relies first on cultural and biological control methods and uses chemical controls only when needed.

The economic risk to cotton growers posed by "sticky cotton" is extreme. If a region is associated with this problem by spinning mills, future sales can be eliminated or discounts applied. Preserving the integrity of the cotton quality is paramount to cotton production.

Role of Chlorpyrifos: Chlorpyrifos is an important IPM component later in the season when lint is exposed. It is used in tank mixes with pyrethroids to knock down sudden influx of adults. Tank mixes are used to control multiple stages of whitefly (adults, immatures, and eggs). Sometimes three chemicals are tank mixed to attack different life stages. Loss of older chemicals (organophosphates, carbamates, organochlorines) drives chlorpyrifos use. Limited numbers of AIs are available for quick knock-down of migrating adult populations.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Severe, if bolls open
Damage	Feeding from phloem, secretion of honeydew is deposited on open lint; loss of quality; loss of reputation and marketability
Frequent or Occasional Pest	Frequent
Regionality	Southern Deserts Valleys (key pest); Southern SJV (frequent pest), northern SJV (occasional)
Timing of Outbreaks	Early and mid-season to harvest

Alternative Active Ingredients (AI)

Early to Mid- Season: Insect growth regulators are the first line of defense (Stage I), followed by selective insecticides (Stage 2). Tank mixes of pyrethroids and organophosphates/carbamates should be avoided until late in season (Stage III) in order to preserve natural enemies and avoid secondary outbreaks of other pests. The goal is to hold down pests before chlorpyrifos and broad-spectrum materials are used. For details, see Cotton PMG.

Late Season

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Bifenthrin	Capture	3A	0.62	Can be alone or tank mixed
Fenpropathrin	Danitol	3A	NA	Use in combination with the following
Oxamyl	Vydate	1A	2.13	
Acephate	Orthene	1B	0.55	
Chlorpyrifos	Lorsban	1B	1.00	

Danitol is used as a tank mix partner for Vydate, Orthene and chlorpyrifos, no direct comparison necessary.

Alternative Management Practices

Practice	Comments
Cultivar selection	Pima cultivars appear to be more susceptible to whitefly infestations and associated damage. Within the Acala cotton cultivars, hairy-leaf varieties, which comprise the majority of the market, are more susceptible to aphids than are smooth-leaf varieties. Not known what the pest pressure is when selecting cultivar so selection more about other factors rather than pest management
Conserve natural enemies	Avoid the use of broad spectrum materials during early and mid-season
Good field sanitation of alternate crop hosts and weeds in winter and spring	Remove potential sources of whiteflies, e.g., melons; requires cooperation with neighboring farmers
Early crop termination and defoliation	Dependent on seasonal weather conditions
Regional pest management	Plant cotton at least one-half mile upwind from other key whitefly hosts; Prompt residue sanitation after harvest for adjacent host crops; requires neighborhood cooperation.

Other Considerations and Knowledge Gaps

Research	Policy	Education
Monitoring and decision-making protocols to San Joaquin Valley conditions	Removal of registrations for older chemical AIs (organophosphates, carbamates, organochlorines) is driving chlorpyrifos use.	Renew awareness of sticky cotton Improved networking to provide current situational updates of whitefly distribution Reinforce critical importance of early season scouting. Encourage cooperation in removing key crop hosts that serve as sources of whiteflies

Brown Stinkbug

Euschistus servus

Brown stinkbug is a newly introduced pest appearing in the Palo Verde Valley, Riverside County in 2013. This pest has become a problem throughout the southeastern U.S. cotton belt. Recently introduced in Arizona, the management of this pest has been very disruptive to the well-tuned cotton IPM system.

Under normal circumstances and in general, stink bugs do not feed on squares. Stink bugs are seed-feeding insects. They prefer larger bolls with developing seed. When a field is first flowering and brown stinkbug have nothing else to feed on, they can and will feed on the smaller, 1–3 day old bolls beneath the flowers and can cause young boll shed. Besides boll shed, brown stink bug feeding can cause misshapen bolls (so called "parrot beak" bolls) and hard lock bolls. In both cases, the cotton lint does not release as the boll opens and it is therefore not harvestable. Feeding can also introduce pathogens such as boll rot organisms although the importance of this in the arid western environments is unknown.

No information regarding brown stinkbug is available from San Joaquin Valley. However, based on experiences from Palo Verde Valley, this pest will cause late season damage and major losses.

Role of Chlorpyrifos: Information from Arizona indicates that chlorpyrifos is not a very effective choice, further research required.

Pest Status

Attribute	Status
New or Established Pest	New
Potential for Severity/ Economic Loss	Severe threat
Damage	Feeding on seeds in bolls, loss of bolls, staining of lint
Frequent or Occasional Pest	Unknown
Regionality	Currently only in Palo Verde Valley, Riverside Co
Timing of Outbreaks	Mid-late season

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Dicrotophos	Bidrin	1B	Unknown	Not registered in CA
Bifenthrin	Capture	3A	Rates Untested in California	Broad spectrum, can create aphid problems
Bifenthrin + zeta cypermethrin	Hero	3A	Rates Untested in California	Broad spectrum
Acephate	Orthene	1B	Rates Untested in California	Broad spectrum can flare mites
Chlorpyrifos	Lorsban	1B		Not on Label

Alternative Management Practices: None identified

Other Considerations and Knowledge Gaps

Research	Policy	Education
Biology, bioeconomics, ecology, sampling, decision aids	Re-registration of older products	Need to get word out: • Identification • Biology • Sampling, assessment • Decision aids

Cotton Aphid – Early-mid Season
Aphis gossypii

This is the same insect as presented earlier, but occurring earlier in the season when it is much less a threat and alternative AIs and practices are available. This sucking insect taps into the phloem, extracts the sap, removes nitrogenous compounds, and excretes concentrated sugary fluids. While damage in early (stunting, leaf cupping, and reduction in general plant vigor) season can occur, it does not threaten the quality of the cotton lint.

Role of Chlorpyrifos: Chlorpyrifos is an important IPM component later in the season when lint is exposed. At this time of year, growers depend on two primary active ingredients (4A neonicotinoid and 9C flonicamid). Chlorpyrifos adds a third AI during this early-mid season period time period, but rarely used.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Light to moderate threat
Damage	Plant stunting, reduction in stand, loss of vigor
Regionality	Mostly San Joaquin Valley issue
Frequent or Occasional	Usually present, occasional pest
Timing of Outbreaks	Early season through late season

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Imidacloprid	Admire flowable	4A	3.42	Used in drip irrigated cotton
Imidacloprid	Provado, Trimax Pro (also part of the premix called Leverage with Baythroid)	4A	NA	Foliar application
Acetamiprid	Assail	4A	2.72	Very effective, mid-season, 28 PHI
Flonicamid	Carbine	9C	1.84	Good control, effective on Lygus nymphs
Thiamethoxam	Centric	4A	0.85	Mixed results since formulation changed, need higher rate registered
Thiamethoxam	Cruiser seed treatment	4A	0.30	Seed treatments have limited residual, earliest season only
Pymetrozine	Fulfill	9B	2.18	Partial control, limited availability in California cotton market
Imidacloprid	Gaucho seed treatment	4A	0.27	Seed treatments have limited residual, earliest season only
Insecticidal Soap	Insecticidal Soap UC	UC	2.69	Not very effective. Available for organic use
Methomyl	Lannate	1A	0.54	Broad spectrum, Danger Poison signal word, additional safeguards
Oxydemeton-Methyl	MSR	1B	2.65	No longer used
Narrow Range Oil	Narrow Range Oil UC	UC	0.42	Organic option
Azadirachtin	Neemix	UC	2.67	Partial control, available for organic use
Acephate	Orthene	1B	1.16	In-furrow application at planting is effective for only a short time
Chlorpyrifos	Lorsban	1B	1.00	Not first choice, other AIs available

Alternative Management Practices

Practice	Comments
Conserve natural enemies	Avoid the use of broad spectrum materials during early and mid-season
Cultivar selection	Pima cultivars appear to be more susceptible to aphid infestations and associated damage. Within the Acala cotton cultivars, hairy-leaf varieties, which comprise the majority of the market, are more susceptible to aphids than are smooth-leaf varieties. Not known what the pest pressure is when selecting cultivar so selection more about other factors rather than pest management
Propagate and add habitat for natural enemies	Some growers are using a mixture of plants along the edge of cotton fields to provide shelter, nutrition and prey for natural enemies.

Other Considerations and Knowledge Gaps

Research	Policy	Education
Aphid and resistant varieties, transgenic options Is planting date really effective at aphid control? Additional research to improve sampling and assessment protocols, especially in time period just weeks before open bolls.	Are there any new pesticide products to address aphids? How well will Transform work Additional PUR information would be useful in understanding chlorpyrifos use patterns,.e.g. target species Can Platinum get cotton registration through drip? Removal of registrations for older chemical AIs (organophosphates, carbamates, organochlorines) is driving chlorpyrifos use.	Is the current monitoring and decision making tools well understood?

Lygus Bugs
Lygus hesperus

Lygus bugs are the key pest in San Joaquin Valley cotton. Lygus bugs can threaten a cotton crop from early squaring (bud formation) through final boll set. Lygus bugs pierce squares (floral buds) and damage anthers and other tissues. When squares are less than 0.2 inch long, they shrivel, turn brown, and drop from the plant. If many squares drop, the plant may put its energy resources into vegetative growth, resulting in tall, spindly plants, prolonging the production season and reducing yields. Lygus bugs also feed on and destroy terminal meristems, causing bushy plants. If these bugs pierce the wall of young bolls (typically less than 10 days old) and feed on young seeds, these seeds may fail to develop. Lint around the injured seeds is stained yellow, and may do not mature normally.

Lygus bugs migrate to cotton from other hosts, so management of this pest begins with assessing its populations outside the field. Check for them on weeds, in nearby alfalfa, and in other crops, e.g., safflower, and keep in touch with your pest control adviser, or farm advisor for area-wide information on Lygus bug populations. Proper management of alfalfa harvest can reduce damaging migrations to cotton. The need for insecticides in cotton must be evaluated carefully on a field-by-field basis, as treatments may result in secondary outbreaks of spider mites, aphids, or other pests.

Role of Chlorpyrifos: Chlorpyrifos is not generally utilized for Lygus control. However, chlorpyrifos might go into a tank mix if other pests are present and could be important for rotation to mitigate the development of insecticide resistance. Chlorpyrifos is used after August, could be used in combination with pyrethroids, and is likely to be used during years where Lygus arrive over an extended period, requiring multiple applications of insecticides.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Severe loss
Damage	Reduction of fruit, excessive plant growth, increased water demand and extended season to compensate for loss
Frequent or Occasional Pest	Frequent, but location dependent
Regionality	Key pest in San Joaquin and Sacramento Valleys; present in southern desert valleys.
Timing of Outbreaks	Early and mid-season once fruiting buds are present until last harvestable boll is 10 days past flowering

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Beta-cyfluthrin	Baythroid	3A	0.56	Broad spectrum, does not conserve natural enemies. Can increase mite and aphid problems
Clothiandin	Belay	4A	1.12	Partial control, issues with bees
Bifenthrin	Capture	3A	0.60	Broad spectrum, does not conserve natural enemies. Can increase mite and aphid problems
Flonicamid	Carbine	9C	1.50	Important early season, selective to Lygus, does not overly impact natural enemy populations; controls aphids
Novaluron	Diamond, Mayhem	15	1.20	Partial control, suppression of populations
Dimethoate	Dimethoate	1B	0.45	Broad spectrum, does not conserve natural enemies
Beta-cyfluthrin & imidacloprid	Leverage	Premix 3A, 4A	1.10	Good efficacy. Broad spectrum, can increase mite outbreaks
Acephate	Orthene	1B	0.81	Good efficacy. Broad spectrum, does not conserve natural enemies. Can increase mite pressure.
Indoxacarb	Steward	22A	2.34	Suppression of populations, sometimes combined with other products
Oxamyl	Vydate	1A	2.07	Broad spectrum, avoid use in early and mid-season
Lambda-cyhalothrin	Warrior	3A	0.34	Partial control, broad spectrum, does not conserve natural enemies. Can increase mite problems
Chlorpyrifos	Lorsban	1B	1.00	Rarely used unless other pests are present or extended Lygus populations are present.

Alternative Management Practices

Practice	Comments
Conserve natural enemies	Natural enemies can moderate populations; general predators are key component in causing Lygus mortality; avoid broad spectrum AIs early and mid-season
Propagate companion habitat strips for natural enemies	Some growers are using a mixture of plants along the edge of cotton fields to provide shelter, nutrition and prey for natural enemies
Develop cooperative regional management plans	Cooperate with neighbors to manage crops which act as Lygus source
Manage neighboring crops	Strip cut alfalfa; timed insecticides in safflower; monitor insect movement from seed alfalfa

Other Considerations and Knowledge Gaps

Research	Policy	Education
Status of transgenic cotton against Lygus How valuable are companion habitat strips for insect management?	Increased number of insecticide registrations in source crops; e.g. safflower and seed alfalfa	None noted

Cutworms
Agrotis spp.

Cutworm larvae chew young plants off at the base at or near ground level. Damage is usually limited to certain parts of a field and may reoccur each season in the same place. Usually several plants in the same row are damaged. Cutworms can live in soil and are usually not seen until damage is observed.

Cutworms may become a problem if good field sanitation practices are not used and residue from a previous crop is allowed to remain in the field over the winter. Allow time for previous crop residues to decompose and destroy vegetation from weeds and cover crops for at least 3-4 weeks before planting to minimize the cutworm problem. Can be an increasing problem in fields where conservation tillage is practiced.

Role of Chlorpyrifos: Chlorpyrifos is an essential insecticide in the event of an early season cutworm problem. Although outbreaks are infrequent and occur sporadically, chlorpyrifos plays an essential role in controlling outbreaks.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Not a large threat
Damage	Mortality to seedlings can cause stand vigor issues
Frequent or Occasional Pest	Occasional and occurring sporadically
Regionality	Throughout California
Timing of Outbreaks	Early season during germination and stand establishment

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Acephate	Orthene in-furrow at planting	1B	1.19	Requires advance knowledge of an outbreak, so based on experience of potential threat in that field
Indoxacarb	Steward	22A	NA	Not on Label
Chlorpyrifos	Lorsban	1B	1.00	Effective when contact is made

Alternative Management Practices

Practice	Comments
Good field sanitation of previous crop residue and weeds	Allow time for previous crop residues to decompose

Beet Armyworm
Spodoptera exigua

Beet armyworm (BAW) destroys seedlings, terminals of young plants, and squares and small bolls during early July. Early season infestations may develop on weeds and move to cotton when weeds are controlled, destroying seedling cotton or the terminals of older plants. The loss of a majority of squares and bolls during July or August may reduce yield or delay maturity by delaying fruit set. Severe defoliation may cause crop loss as well.

In addition to cotton, beet armyworms feed on alfalfa, vegetables, sugarbeets, beans, and weeds such as pigweeds and nettleleaf goosefoot. In occasional years, there may be widespread outbreaks when favorable weather allows exceptionally large populations to build up early in the season on alternate hosts. Damaging populations may also occur where insecticides applied for other pests reduce natural enemy populations. Watch for beet armyworm on adjacent crops and on weeds in and around the field. Treatment of a limited area, such as a strip at the edge of the field, is usually successful. When selecting an insecticide from a group of effective products, always select the insecticide that is least harmful to natural enemies.

Role of Chlorpyrifos: Chlorpyrifos is not the first active ingredient to be considered. However, it is still important to have in the mix when materials are not working or BAW is present with several other pests.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate threat
Damage	Seedling death reduces stand vigor, foliar feeding, loss of fruit resulting in direct yield loss
Frequent or Occasional Pest	Usually present, occasional pest
Regionality	Throughout California
Timing of Outbreaks	Can occur early or late in the season

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Group Mode of Action	Cost Comparison Relative to Lorsban	Comments
Esfenvalerate	Asana	3A	0.46	Broad spectrum, avoid using early in the season
Flubendiamide	Belt	28	1.54	Selective, good efficacy
Bifenthrin	Capture	3A	0.68	Broad spectrum, avoid using early in the season
Chlorantraniliprole	Coragen	28	5.68	Selective, very effective
Novaluron	Diamond, Mayhem	15	1.20	Partial control, slow acting, must treat when worms recently hatched
Diflubenzuron	Dimilin	15	1.14	Very slow acting
Bacillus thuringiensis	Xentari, Agree	11B1	1.98	Partial control, must treat when small worms are newly hatched
Methoxyfenzoide	Intrepid	18	1.46	Selective, effective
Methomyl	Lannate	1A	0.04	Broad spectrum, Danger Poison signal word, additional safeguards
Thiodicarb	Larvin	1A	2.98	Works well, availability questioned
Spinosad	Success	3A	3.36	Works well, low impact on natural enemies
Chlorpyrifos	Lorsban	1B	1.00	Not first choice

Alternative Management Practices

Practice	Comments
Conserve natural enemies	Both predators and parasites are important in maintaining population densities below damaging levels, avoid broad spectrum AIs early
Utilize transgenic cotton varieties	Upland Acala varieties only; not Pima
Control weeds on margins	Useful against a number of pests

Other Considerations and Knowledge Gaps

Research	Policy	Education
Bt transgenic Pima	None noted	None noted

Pink Bollworm

Pectinophora gossypiella

Pink bollworms damage squares and bolls; the damage to bolls being the most serious. Larvae burrow into bolls, through the lint, to feed on seeds. As the larva burrows within a boll, lint is cut and stained, resulting in severe quality loss. Under dry conditions, yield and quality losses are directly related to the percentage of bolls infested and the numbers of larvae per boll. With high humidity, it only takes one or two larvae to destroy an entire boll because damaged bolls are vulnerable to infection by boll rot fungi.

When high population levels of pink bollworm occur, the objectives of management are to keep infestations below damaging levels in the current season—without creating secondary outbreaks of other pests—and to reduce the overwintering population that will threaten the following season's crop. The main control tools are observance of host-free period (San Joaquin Valley), the judicious use of insecticides, timely crop termination and harvest, rapid crop destruction, properly timed winter and spring irrigations, and compliance with plow down requirements. When pink bollworms are found in the San Joaquin Valley, a regional monitoring and sterile moth release program is implemented.

Currently pink bollworm is under an international effort to eradicate this pest. Populations have declined substantially due to area wide planting of transgenic Bt cotton, mass release of sterile males, and mating disruption activities. This is especially true in the southern Califonria production area where pink bollworm has historically been a significant pest.

Role of Chlorpyrifos: Chlorpyrifos has been important in managing pink bollworm. However, as populations decline due to widespread use of Bt cotton, it is less often used.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Severe loss
Damage	Destroys fruit buds, flowers and bolls
Frequent or Occasional Pest	Frequent where established, infrequent in SJV and eradication areas
Regionality	Desert valleys and infrequent in SJV
Timing of Outbreaks	Mid- to late season, flowering through boll development

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Esfenvalerate	Asana	3A	0.27	Little experience with chemical control, managed by cultural methods and exclusion
Cypermethrin	Cypermethrin	3A	0.32	
Indoxacarb	Steward	22A	2.62	
Spinosad	Success	5	3.36	
Chlorpyrifos	Lorsban	1B	1.00	

Alternative Management Practices

Practice	Comments
Mating disruption	Sterile male program and pheromone mating disruption has worked well
Sterile male releases when required	Very effective in preventing establishment in SJV
Utilize transgenic cotton	Very effective, no transgenic Bt Pima cotton
Host free period – mandated plow down and planting	Very successful in preventing overwintering survival. Post-harvest sanitation in some conflict with minimum tillage (conservation tillage) practices
Avoid late irrigation & fertilization	Produce crop in shortest time possible to minimize the number of pest generations
Good field sanitation of crop residue and weeds	Removes sources of infestation

Other Considerations and Knowledge Gaps:

There is a need to evaluate and develop Bt Pima varieties

Seedcorn Maggot

Delia platura

Damage generally occurs in localized areas of the field and appears as areas where seedlings have not emerged. Seed corn maggots hollow out seeds or eat portions of seedlings. Damage is most common in early plantings when the soil is cool, especially in fields with abundant organic matter. Damage tends to be worse on sandier soils.

If cotton follows corn in a crop rotation, seed corn maggot may become a problem, especially if crop residue is present in the soil for the maggot to overwinter on. Once damage occurs it is too late to treat. A slurry seed treatment is the best preventive control if cotton must be planted early in fields with high levels of decaying organic matter. Planting later in spring when the soil isn't excessively moist and soil temperatures are warmer will help to reduce damage by this pest. Also, destroying vegetation from the previous crop at least one month before planting should help minimize damage.

Role of Chlorpyrifos: Chlorpyrifos is registered as a seed treatment but is not common anymore. This pest is not on labels for some chlorpyrifos products.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate
Damage	Loss of stand, replanting may be required, delay of establishment
Frequent or Occasional Pest	Occasional
Regionality	Throughout California
Timing of Outbreaks	Early spring

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Acephate	Orthene in-furrow at planting	1B	1.19	Must be able to predict problem; Not in PMG
Acephate	Seed Treatment	1B	0.1	Must be able to predict problem well in advance to order seed; not in PMGs
Lorsban	Chlorpyrifos	1B	1.00	Seed treatment, Must be able to predict problem

Alternative Management Practices

Practice	Comments
Later planting and irrigation management	May conflict with aphid and whitefly management
Crop rotation	Avoid planting cotton after corn
Good field sanitation of crop residue and weeds	Field residue sanitation at least 1 month before planting. Increasing problem with no till/minimum till situations

Other Considerations and Knowledge Gaps: None noted

Wireworms

Limonius spp.

Wireworms are the soil-dwelling larvae of click beetles. Wireworms destroy germinating seeds and tiny seedlings. Often the wireworm will be found near the damaged or missing seed or plant. Even if the damage does not completely destroy the plant, the feeding wounds may predispose the plant to seedling diseases.

Wireworms may be a problem following an alfalfa rotation or in fields that were previously pastures. Cultivating, flooding, and dry fallowing can help reduce population. If wireworms are present in the soil, a preventive seed treatment may be necessary. Limited seed treatment options exist for this pest. Once wireworm is established in a field, it is nearly impossible to treat.

Role of Chlorpyrifos: Chlorpyrifos has been is used as a seed treatment but currently is rarely used in this application anymore.

Pest Status

Attribute	Status
New or Established Pest	Established
Potential for Severity/ Economic Loss	Moderate
Damage	Reduction of stand, reduction of plant vigor, replanting may be required, delay of production season
Frequent or Occasional Pest	Occasional except where established in specific field, then frequent
Regionality	Throughout California
Timing of Outbreaks	Early season during germination and stand establishment

Alternative Active Ingredients (AI)

Active Ingredient	Trade Name(s)	IRAC Mode of Action Group	Cost Comparison Relative to Lorsban	Comments
Acephate	Orthene in-furrow	1B	NA	Requires knowledge of pest presence before crop is planted, Not on label
Acephate	Orthene ST	1B	NA	Not on label
Chlorpyrifos	Lorsban	1B	1.00	Seed treatment, Must be able to predict problem

Alternative Management Practices

Practice	Comments
Preplanting field cultivation flooding, and dry fallowing	Not practical in water limited areas and years
Crop Rotation	Avoid planting cotton after alfalfa

Other Considerations and Knowledge Gaps

Research	Policy	Education
Improved detection methods Additional preventive treatment options needed Increasing problem in no till/minimum till situations	None noted	None noted

Summary and Recommendations for an Action Plan

Summary

Public concerns about environmental and human health risks posed by chlorpyrifos and pesticides, in general, are well recognized by the agricultural industry. There is agreement by the Alfalfa, Almond, Citrus and Cotton Teams that these concerns motivate continuous stewardship efforts surrounding chlorpyrifos use.

Chlorpyrifos plays a unique and important role in IPM for the pests identified through this facilitated discussion process. The Crop Teams emphasized this active ingredient needs to remain in the toolbox as an effective option to manage critical pest issues or when a combination of pest pressures occasionally occurs.

The Crop Teams agree that thoughtful consideration is in order when weighing treatment options that might include chlorpyrifos. Growers and PCAs are aware that the decision making process should ensure all alternative active ingredients and practices are considered and mitigation of risk has been carefully implemented when needed.

The Crop Teams are committed to promoting the safe and judicious use of chlorpyrifos through enhanced training to IPM practitioners, pest control advisors and extension personnel as the science and technology evolve. New practices will need field demonstration and, as new active ingredients are registered, it is extremely important that these products have international MRLs are established concurrent with US registrations and included in UC PMGs.

General Recommendations

There is a real opportunity to strengthen integrated pest management programs that use chlorpyrifos as a key pest management tool. Our general recommendations are to:

• *Continue to gather scientific information to improve our management of chlorpyrifos in those situations where consideration of all available alternative active ingredients and practices has deemed its use necessary*

• *Use mitigation practices to prevent runoff, drift and human exposure*

• *Build upon the success of existing stewardship initiatives such as SpraySafe, CURES and USDA Natural Resources Conservation Service (NRCS) to communicate issues, concerns and practices related to safe and effective use of chlorpyrifos and all pesticides*

• *Establish public education programs to increase awareness and understanding of pest management and stewardship activities required to produce food, forage and fiber*

Research

Sufficient numbers of trained personnel within the university and extension system will be required to develop and deliver scientifically validated information to support alfalfa, almond, citrus and cotton IPM programs that utilize chlorpyrifos. Specific activities with the most long-term benefits:

• *Study pest biology, pest interactions and crop development*

• *Improve, revise and create practical scouting and assessment protocols which provide reliable metrics for decision making*

• *Provide training to increase the use of alternative reduced risk management practices utilized*

• *Evaluate PUR data to identify areas for focused outreach*

• *Develop, evaluate and register effective insecticides*

• *Establish MRLs for all pesticides used in exported commodities*

Education & Extension

An ongoing effort to develop and deliver knowledge and information in a practical and accessible format is required for farmers and PCAs to understand the value and need to steward chlorpyrifos.

Key steps to address the needs are:

1. Continual review and updates of existing educational products, e.g. PMGs, on the risks and benefits of chlorpyrifos in IPM including existing responsibilities and regulatory requirements and mitigation of risk

2. Create decision support tools that:
• *Incorporate the latest research findings*

• *Provide guidance to best management practices and regulatory requirements*

• *Are based on identifiable pest and production metrics*

3. Conduct on-farm demonstrations and utilize on-line technology to:

• Showcase innovative approaches

• Compare and contrast existing vs. alternative approaches

• Create an environment in which experimental problem solving is encouraged as a community activity

Develop programs to train and equip PCAs and field experts will be required to take on more complex technical and regulatory issues.

Policy

In order to accomplish the action plan described in this report, changes in organizations must take place:

• CDPR is requested to:

a) Develop comprehensive, science-based information about the specific risk(s) and risk pathways posed by chlorpyrifos

b) Clearly articulate their concerns to the agricultural industry

c) Work with the industry to develop any additional mitigation and prevention approaches to address their concerns

• Improve data collection, management and presentation of CDPR Pesticide Use Records to track and measure changes in use patterns

• Invigorate independent UC IPM funding to address longer term research and extension goals, e.g. cropping ecosystems, cyclic nature of pest outbreaks, pest biology and building confidence in the IPM approaches including, monitoring, action thresholds and alternative tactics and insecticides

• Create diverse partnerships with the University, government, industry, registrants, production agriculture and other sectors in order to create a dynamic climate for team problem solving

• Encourage the U.S. EPA and registrants to proactively establish MRLs and to work with other regulatory bodies to improve the international MRL harmonization process

• Streamline the research and development process to register new chemistries and reduce barriers to product registration of alternative products

• Establish clear goals and timelines to address attrition in traditional university and extension systems

• Create mechanisms to attract, recruit and train field personnel to address future staffing needs in the areas of crop production, pest management and stewardship

Support Tools for Chlorpyrifos Decision Making

It was emphasized in the Crop Team discussions that the decision to use chlorpyrifos is a part of an iterative process. While the components can be simplified, individual situations will ultimately depend on the expertise and experience of the PCA, the unique on-the-ground reality of the moment, and the production constraints of the grower.

UC IPM Pest Management Guidelines provide the essential foundation that already supports pest control decisions. As part of this Chlorpyrifos Project, UC IPM will work with the Crop Teams to improve this established framework by developing innovative decision support tools.

The following principles are intended to guide the development of the decision support tool:

1. When available, cultural practices have been implemented which avoid or prevent a pest outbreak. Examples of practices include use of resistant cultivars, optimizing planting and harvest dates, optimizing nutrient and irrigation management, and crop sanitation.

2. The decision support process is dictated by availability of alternative active ingredients and practices.

3. An understanding of the role of biological control in the particular system is important in understanding pest population growth.

4. The decision process must be flexible to incorporate the complexity of the presence of other pests, production goals, constraints within the system and balance the benefits and risks.

5. UC IPM Pest Management Guidelines provide the foundational information and require continual updating.

6. Seeking the experience and knowledge of the PCA and farmer is important in developing a practical and robust tool.

7. Record keeping is an important component for continued improvement of any IPM program.

One early concept for a decision support tool is to use a technically robust checklist. Currently, static checklists are utilized in the year round IPM program as reminders of what activities should be considered during specific periods of crop development.

As an educational tool, the checklist should be dynamic and flexible to provide an overview of key steps in the process while also allowing for delving deeper into the information resources. As an on-line tool, it has the advantage of being interactive, providing many links to multiple learning opportunities including identification resources, short training videos, comparative tables and risk mitigation. For those not utilizing computer applications, printed documents will need to be available.

IPM is a data intensive activity and keeping good records is an important component. It is envisioned that this decision support tool will have the capacity for recording results for future reference and continued improvement in IPM practices. The following table provides a generalized overview of possible steps, information needed and data PCAs generally record. This framework is not proposed as a "one size" fits all IPM situations, but rather is presented as a teaching and tracking tool.

Decision Step	Information Needed	Examples of Data Recorded
Identification of pest	Photo galleries, simple keys (PMG)	Pest(s) present
Sampling protocol	Instructions, (PMG) video illustrations	• Population density of pests • Degree of infestation • Identification and abundance of natural enemies
Treatment threshold	Population density levels (PMG)	• Action Threshold • Population density of pest • Notes on general crop vigor
Evaluate extenuating conditions *(Acknowledges additional complexity of the real cropping ecosystem.)*	Requires development for specific crop and pest. Very specific to location, time of year.	Record extenuating conditions such as • Harvest dates: Are insecticide choices limited by PHI? • Pest complex: Are other pest populations nearing treatment threshold? • Are temperatures affecting insecticide efficacy? • Production conflicts: Irrigation scheduling, weeding crews • Export trade issues: Do alternatives AI have established MRLs?
Management options	Information from PMG and additional resources	
Prevention *(cultural & biological controls)*	Biological and crop information	• Selection of resistant varieties, • Winter sanitation • Habitat augmentation
Suppression *(alternative active ingredients available)*	Review AI options for bystander protection, protection of environment	• Selective for pests • Implications to natural enemy and pollinator population • Runoff potential • Local conditional permits
Mitigation planning	Information from PMG, pesticide mitigation resources	Practices that require production modification e.g. • Irrigation systems • Sediment filters • Vegetative strips
Long term		
Short term		Good management practices which prevent off site drift by air or runoff

Table 6.1. Elements of a conceptual decision support tool.

Next Steps for the Project

The agricultural industries involved in developing this report recognize the need to protect workers, applicators, bystanders and the environment. These groups suggest that the more specific CDPR can be in identifying risk pathways, the more proactive the agricultural industry can be in developing targeted prevention and mitigation practices for the use of chlorpyrifos.

The use of any insecticide in managing pests incurs some risk. California has one of the most comprehensive set of pesticide regulations, which seeks to prevent unintended bystander exposure to pest control activities.

In moving forward, it is important that the information and recommendations developed in this report be turned into practical and meaningful activities that demonstrate the continued commitment of the agricultural community to the safe and effective use of this important active ingredient.

The University of California, through its Cooperative Extension education and outreach programs, is ideally suited to develop and deliver statewide training to support pest control decision making. In combination with the support of the commodity organizations already engaged, the project is extremely well poised to channel new information at the state, regional and local levels.

The public already has at its disposal, a comprehensive set of pest management guidelines for alfalfa, almonds, citrus and cotton provided by UC Statewide IPM Program (UC IPM). These PMGs currently address, in great detail, the majority of challenges and issues raised by this report. The PMGs provide guidance in collecting pest population information and interpreting those data for management purposes, and provide multiple options for management involving both chemical and non-chemical approaches. If an insecticide is required, they provide guidance in choosing the most appropriate insecticide based on risk to people, non-target organisms and the environment, as well as mitigation practices. The PMGs will require frequent updates to maintain its role as a central resource for IPM information.

This information, while very thorough and well organized, is not easily accessible as a support tool for making decisions about use of chlorpyrifos. It is the intention of UC IPM to improve access to this information through a decision support tool. While too early to definitively describe details of the final product, an overview was outlined in the previous section. In addition to the principles and broad outline provided, the level of sophistication of the decision support tool will be determined by programming resources available, the practical needs identified by end users, and the mechanisms for delivery, i.e. mobile smart devices. In addition, for those not inclined to Web/App based products, information will still be available via printed guidelines.

The final phase of this project (Figure 1.2) will be to develop an educational outreach program to improve knowledge of chlorpyrifos usage. These will be developed over the next 16 months (November 2014-March 2016) and will be delivered statewide at meetings directly involving input from Crop Team Leaders and PCA organizations.

Depending on local needs, outreach might include:

• Presentations at key commodity meetings to increase awareness of chlorpyrifos management and the goals of CDPR

• Workshops to provide detailed pest information, components of chlorpyrifos decision making, and hands-on training

• Development of on-line training, if resources are available

The training will cover all aspects of IPM, highlighting the process and resources available to aid decision making. All relevant components necessary for optimal decision making can be made available at training venues, for example, pest identification guides, PMGs, and possibly insect specimens. Training will need to be tailored to audience, crop and location. Additional opportunities could include train-the-trainer, outreach to other agencies (NRCS, County Ag commissioners, etc.).

In conclusion, is the authors' and the Crop Teams' sincere hope that perspectives presented in this report equip the California Department of Pesticide Regulation with information to more fully understand the use and role of chlopyrifos in alfalfa, almond, citrus and cotton IPM systems.

We look forward to working in partnership with the Department and all of its stakeholders to maintain a vibrant and sustainable agricultural production system rooted in respect for the communities and environment in which we live and work.

Resources

Resources

General IPM

Flint, M.L. 2012. IPM in Practice – Principles and Methods of Integrated Pest Management. Second Edition. UC ANR Publication 3418 UC ANR Publication 3312.

NRCS step-by-step instructions for developing a pest management component of a conservation plan. http://www.ipm.ucdavis.edu/PMG/C001/m001yiformsphotos.html.

Mitigation of Risks Associated with Chlorpyrifos

UC IPM WaterTox: Water-Related Risks of Active Ingredients. www.ipm.ucdavis.edu/TOX/simplewatertox.html

CDPR Ground Water Protection Program www.cdpr.ca.gov/docs/emon/grndwtr/index.htm

CURES – Coalition for Urban/Rural Environmental Stewardship. www.curesworks.org

USDA NRCS Programs www.nrcs.usda.gov/wps/portal/nrcs/site/national/home/

SpraySafe – Local water coalitions and county-wide efforts. www.spraysafe.org

Reducing Runoff

Grismer, M.E., A.T. O'Geen, and D. Lewis. 2006. Vegetative filter strips for nonpoint source pollution control in agriculture. UC ANR Publication 8195.

Long, R. J. Gan, and M. Nett. 2005. Pesticide choice: Best Management practices (BMP) for protecting surface water quality in agriculture. UC ANR Publication 8161.

Long, R., A. Fulton, B. Hanson. 2010. Protecting surface water from sediment-associated pesticides in furrow irrigated crops. UC ANR Publication 8403.

O'Geen, A.T., T.L. Prichard, R. Elkins and G.S. Pettygrove. 2006. Orchard floor management practices to reduce erosion and protect water quality. UC ANR Publication 8202.

Prichard, T. (in press) Controlling offsite movement of agricultural chemical residues: Alfalfa. UC ANR Publication. *Expected publication date, early 2015.*

Schwankl, L.J., B.R. Hanson, and T.L. Prichard. 2007. Causes and management of runoff from surface irrigation in orchards. UC ANR Publication 8214.

Schwankl, L.J., T.L. Prichard, B.R. Hanson and R.B. Elkins. 2007. Understanding your orchard's water requirements. UC ANR Publication 8212.

Schwankl, L.J., T.L. Prichard, and B.R. Hanson. 2007. Tailwater return systems. UC ANR Publication 8225.

Alfalfa

Flint, M.L., et al. 2002. Integrated Pest Management for Alfalfa. UC ANR Publication 3312.

Martin, T, et al. 2013. UC IPM Pest Management Guidelines for Alfalfa. UC ANR Publication 3430. Web version: www.ipm.ucdavis.edu/PMG/selectnewpest.alfalfa-hay.html

Relative Toxicities of Insecticides and Miticides Used in Alfalfa to Natural Enemies and Honey bees. www.ipm.ucdavis.edu/PMG/r1900511.html

Almonds

Strand, L.L., et al. 2002. Integrated Pest Management for Almonds. Second Edition. UC ANR Publication 3308.

DeBiase, R., et al. 2014. UC IPM Pest Management Guidelines for Almonds. UC ANR Publication 3431. Web version www.ipm.ucdavis.edu/PMG/selectnewpest.almonds.html

Relative Toxicities of Insecticides and Miticides Used in Almond to Natural Enemies and Honey bees. www.ipm.ucdavis.edu/PMG/r3900311.html

Citrus

Dreistadt, S.H., et al. 2012. Integrated Pest Management for Citrus. Third Edition. UC ANR Publication 3303.

Martin, T.A., e t al. UC IPM Pest Management Guidelines for Citrus. UC ANR Publication 3441. Web version: www.ipm.ucdavis.edu/PMG/selectnewpest.citrus.html

Selectivity of Insecticides and Miticides. www.ipm.ucdavis.edu/PMG/r107300811.html

Cotton

Hake, S.J. et al. 1996. Cotton Production Manual. UC ANR Publication 3352.

Ohlendorf, L.P. et al. 1996. Integrated Pest Management for Cotton in the Western Region of the United States, Second Edition. UC ANR Publication 3305.

Basler, R., et al. 2013. UC IPM Pest Management Guidelines for Cotton. UC ANR Publication 3444. Web version: www.ipm.ucdavis.edu/PMG/selectnewpest.cotton.html

Selectivity of Insecticides and Miticides. www.ipm.ucdavis.edu/PMG/r114900711.html

Selectivity and Persistence of Key Cotton Insecticides/Miticides. www.ipm.ucdavis.edu/PMG/r114900811.html

Summary of Characteristics of Key Cotton Insecticides/ Miticides. www.ipm.ucdavis.edu/PMG/r114900911.html

Appendices

1. List of Chlorpyrifos Formulations and Alternative Active Ingredients by AI
2. List of Chlorpyrifos Formulations and Alternative Active Ingredients by Trade Name
3. Pest by Active Ingredient for Alfalfa
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11. CDPR Pesticide Use Data 2002-2012: Lbs of Chlorpyrifos Used in Cotton

Appendix 1. List of Chlorpyrifos Formulations and Alternative Active Ingredients by AI

Active Ingredient	Trade Name(s)	IRAC MOA	Alfalfa	Almonds	Citrus	Cotton
Abamectin	Clinch	6		✓	✓	
Acephate	Orthene	1B				✓
Acetamiprid	Assail	4A		✓	✓	✓
Azadirachtin	Neemix	IC			✓	✓
Beta-cyfluthrin	Baythroid	3A	✓		✓	✓
Beta-cyfluthrin Imidacloprid	Leverage Premix	Mix 3A, 4A				✓
Bifenthrin	Brigade, Capture	3A		✓		✓
Boric Acid	Boric Acid	UC		✓		
Buprofezin	Applaud, Courier, Centaur	16		✓	✓	✓
Buprofezin Flubendiamide	Tourismo (pre mix)	Mix 16,28		✓		
Carbaryl	Sevin	1A	✓	✓	✓	
Chlorantraniliprole	Altaclor, Coragen	28	✓	✓	✓	✓
Chlorpyrifos	Lock-On	1B	✓			✓
Chlorpyrifos	Lorsban Advanced	1B	✓	✓	✓	✓
Chlorpyrifos	Lorsban 4E	1B	✓	✓	✓	✓
Chlorpyrifos	Lorsban 75G	1B	✓	✓	✓	✓
Chromobacterium Subtsugae Strain	Grandevo	UC			✓	
Clothiandin	Belay	4A		✓		✓
Cryolite	Kryocide	UC			✓	
Cyfluthrin	Baythroid	3A				✓
Cypermethrin	Ammo	3A				✓
Diazinon	Diazinon	1B		✓		
Diflubenzuron	Dimilin	15		✓	✓	✓
Dimethoate	Dimethoate	1B	✓		✓	✓
Dinotefuran	Venom	4A				✓
Emamectin Benzoate	Proclaim	6		✓		
Esfenvalerate	Asana	3A		✓		✓
Fenbutatin Oxide	Vendex	12B			✓	
Fenpropathrin	Danitol	3A		✓	✓	✓

✓ = Use identified by Crop Team

Appendix 1. List of Chlorpyrifos Formulations and Alternative Active Ingredients by AI (Continued)

Active Ingredient	Trade Name(s)	IRAC MOA	Alfalfa	Almonds	Citrus	Cotton
Fenproximate	Fujimite	21A			✓	
Flonicamid	Carbine	9C				✓
Flubendiamide	Belt	28	✓	✓		✓
Imidacloprid	Gaucho	4A				✓
Imidacloprid	Admire Pro	4A			✓	✓
Imidacloprid	Provado and generics	4A				
Indoxocarb	Steward	22A	✓			✓
Insecticidal Soap	Insecticial Soap	UC				✓
Lambda - cyhalothrin	Warrior	3A	✓	✓		✓
Malathion	Malathion	1B	✓		✓	
Metaflumizone	Altrevin	22		✓	✓	
Methidathion	Supracide	1B		✓	✓	
Methomyl	Lannate	1A	✓		✓	✓
Methoprene	Extinguish	7A		✓		
Methoxyfenozide	Intrepid	18	✓	✓		
Naled	Dibrom	1B			✓	
Narrow Range Oil	Narrow Range Oil	UC		✓	✓	✓
Neem Oil	Neem Oil	UC			✓	
Novaluron	Diamond	15				✓
Oxamyl	Vydate	1A				✓
Oxydemeton-Methyl	MSR	1B				
Permethrin	Ambush, Pounce	3A	✓			✓
Phosmet	Imidan	1B	✓	✓		
Pymetrozine	Fulfill	9B				✓
Pyrethrin	Pyganic	3A			✓	
Pyriproxyfen	Seize, Knack	7C		✓	✓	✓
Pyriproxyfen	Esteem Ant Bait	7C		✓	✓	
Spinetoram	Delegate	5		✓	✓	
Spinosad	Success, Entrust	5	✓	✓	✓	✓
Spinosad	Seduce (bait)	5		✓		
Spiromesifen	Oberon	23				✓
Spirotetramat	Movento	23			✓	
Sulfur, (Micronized, wettable)	Sulfur - micronized WP	UC			✓	

✓ = Use identified by Crop Team

Appendix 1. List of Chlorpyrifos Formulations and Alternative Active Ingredients by AI (Continued)

Active Ingredient	Trade Name(s)	IRAC MOA	Alfalfa	Almonds	Citrus	Cotton
Sulfur, Wettable	Sulfur wettable powder	UC			✓	
Thiamethoxam	Cruiser	4A				✓
Thiamethoxam	Actara, Centric	4A			✓	✓
Thiamethoxam	Platinum	4A			✓	
Thimet	Phorate	1B				✓
Thiodicarb	Larvin	1A				✓
Xentari, Agree, Dipel	*Bacillus thuringiensis*	11B	✓	✓	✓	✓
Zeta-cypermethrin	Mustang	3A	✓		✓	

✓ = Use identified by Crop Team

Appendix 2. List of Chlorpyrifos Formulations and Alternative Active Ingredients by Trade Name

Trade Name(s)	Active Ingredient	IRAC MOA	Alfalfa	Almonds	Citrus	Cotton
Actara, Centric	Thiamethoxam	4A			✓	✓
Admire Pro	Imidacloprid	4A			✓	✓
Altaclor, Coragen	Chlorantraniliprole	28	✓	✓	✓	✓
Altrevin	Metaflumizone	22		✓	✓	
Ambush, Pounce	Permethrin	3A	✓			✓
Ammo	Cypermethrin	3A				✓
Applaud	Buprofezin	16		✓	✓	
Asana	Esfenvalerate	3A		✓		✓
Assail	Acetamiprid	4A		✓	✓	✓
Bacillus thuringiensis	Xentari,Agree, Dipel	11B	✓	✓	✓	✓
Baythroid	Beta-cyfluthrin	3A	✓		✓	✓
Belay	Clothiandin	4A		✓		✓
Belt	Flubendiamide	28	✓	✓		✓
Boric Acid	Boric Acid	UC		✓		
Brigade, Capture	Bifenthrin	3A		✓		✓
Carbine	Flonicamid	9C				✓
Centaur, Courier	Buprofezin	16		✓	✓	✓
Clinch	Abamectin	6		✓	✓	
Cruiser	Thiamethoxam	4A				
Danitol	Fenpropathrin	3A		✓	✓	✓
Delegate	Spinetoram	5		✓	✓	
Diazinon	Diazinon	1B		✓		
Dibrom	Naled	1B			✓	
Dimethoate	Dimethoate	1B	✓		✓	✓
Dimilin	Diflubenzuron	15		✓	✓	✓
Entrust, Success	Spinosad	5	✓	✓	✓	✓
Esteem Ant Bait	Pyriproxyfen	7C		✓	✓	

✓ = Use identified by Crop Team

Appendix 2. List of Chlorpyrifos Formulations and Alternative Active Ingredients by Trade Name (Continued)

Trade Name(s)	Active Ingredient	IRAC MOA	Alfalfa	Almonds	Citrus	Cotton
Extinguish	Methoprene	7A		✓		
Fujimite	Fenproximate	21A			✓	
Fulfill	Pymetrozine	9B				✓
Gaucho	Imidacloprid	4A				✓
Grandevo	Chromobacterium Subtsugae Strain	UC			✓	
Imidan	Phosmet	1B	✓	✓		
Insecticial Soap	Insecticidal Soap	UC				✓
Intrepid	Methoxyfenozide	18	✓	✓		
Kryocide	Cryolite	UC			✓	
Lannate	Methomyl	1A	✓		✓	✓
Larvin	Thiodicarb	1A				✓
Leverage Premix	Beta-cyfluthrin Imidacloprid	Mix 3A, 4A				✓
Lock-On	Chlorpyrifos	1B	✓			✓
Lorsban 4E	Chlorpyrifos	1B	✓	✓	✓	✓
Lorsban 75G	Chlorpyrifos	1B	✓	✓	✓	✓
Lorsban Advanced	Chlorpyrifos	1B	✓	✓	✓	✓
Malathion	Malathion	1B	✓		✓	
Movento	Spirotetramat	23			✓	
MSR	Oxydemeton-Methyl	1B				
Mustang	Zeta-cypermethrin	3A	✓		✓	
Narrow Range Oil	Narrow Range Oil	UC		✓	✓	✓
Neem Oil	Neem Oil	UC			✓	
Neemix	Azadirachtin	UC			✓	✓
Novaluron	Diamond	15				✓
Oberon	Spiromesifen	23				✓
Orthene	Acephate	1B				✓
Thimet	Phorate	1B				✓
Platinum	Thiamethoxam	4A			✓	

✓ **= Use identified by Crop Team**

Appendix 2. List of Chlorpyrifos Formulations and Alternative Active Ingredients by Trade Name (Continued)

Trade Name(s)	Active Ingredient	IRAC MOA	Alfalfa	Almonds	Citrus	Cotton
Proclaim	Emamectin Benzoate	6		✓		
Provado and generics	Imidacloprid	4A				
Pyganic	Pyrethrin	3A			✓	
Seduce (bait)	Spinosad	5		✓		
Sevin	Carbaryl	1A	✓	✓	✓	✓
Seize, Esteem, Knack	Pyriproxyfen	7C		✓	✓	✓
Steward	Indoxocarb	22A	✓			✓
Sulfur - micronized WP	Sulfur, (Micronized, wettable)	UC			✓	
Sulfur wettable powder	Sulfur, Wettable	UC			✓	
Supracide	Methidathion	1B		✓	✓	
Tourismo (pre mix)	Buprofezin Flubendiamide	Mix 16,28		✓		
Vendex	Fenbutatin Oxide	12B			✓	
Venom	Dinotefuran	4A				✓
Vydate	Oxamyl	1A				✓
Warrior	Lambda - cyhalothrin	3A	✓	✓		✓

✓ = Use identified by Crop Team

Appendix 3. Pest by Active Ingredient for Alfalfa

Product			Key Pests, No or Few Alternative AIs or Practices Available			Important Pests with Alternative AIs or Practices Available			Occasional Pests or Pests with Alternative AIs or Practices Available			
Trade Name(s)	Active Ingredient	IRAC MoA	Aphid, Alfalfa	Aphid, Cowpea	Weevils Blue	Aphid, Pea	Alfalfa caterpillar	Armyworm, Beet & Yellow striped	Aphid, Spotted Alfalfa	Leafhoppers	Webworm	Cutworms, variegated, granulate & army
Ambush, Pounce	Permethrin	3A								✓	✓	✓
Baythroid	Beta-cyfluthrin	3A	✓	✓	✓	✓			✓	✓	✓	✓
Belt	Flubendiamide	28					✓	✓			✓	✓
Dimethoate	Dimethoate	1B	✓	✓		✓			✓	✓		
Coragen	Chlorantraniliprole	28					✓	✓				
Entrust	Spinosad	5			✓							
Imidan	Phosmet	1B			✓					✓		
Intrepid	Methoxyfenozide	18					✓	✓			✓	
Lannate	Methomyl	1A	✓				✓	✓		✓		
Lock-On	Chlorpyrifos	1B					✓	✓			✓	
Lorsban 4E	Chlorpyrifos	1B	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lorsban Advanced	Chlorpyrifos	1B	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Malathion	Malathion	1B	✓	✓	✓	✓			✓	✓		
Mustang	Zeta-cypermethrin	3A	✓	✓	✓	✓			✓	✓	✓	
Sevin	Carbaryl	1A								✓	✓	
Steward	Indoxocarb	22A			✓		✓	✓				✓
Warrior	Lambda - cyhalothrin	3A	✓	✓	✓	✓			✓	✓	✓	✓
Xentari, Dipel ES	*Bacillus thuringiensis*	11B					✓	✓			✓	

✓ = Use identified by Crop Team

Appendix 4. Pest by Active Ingredient for Almonds

Product			Key Pests, No or Few Alternative AIs or Practices Available		Important Pests with Alternative AIs or Practices Available						Occasional Pests or Pests with Alternative AIs or Practices Available			
Trade Name(s)	Active Ingredient	IRAC MOA	Leaffooted Bug	Stink Bugs	Ants - Protein feeding	European Fruit Lecanium	Navel Orangeworm	Oriental Fruit Moth	Peach Twig Borer	San Jose Scale	Tree Borers (Prune Limb, American Plum)	Ten-lined beetle	Fuller rose beetle	Leaf rollers
Altaclor, Coragen	Chlorantraniliprole	28					✓	✓	✓					✓
Altrevin	Metaflumizone	22			✓									
Asana	Esfenvalerate	3A	✓	✓			✓		✓		✓			
Assail	Acetamiprid	4A							✓					
Baythroid	Beta-cyfluthrin	3A							✓		✓			
Belay	Clothiandin	4A	✓	✓										
Belt	Flubendiamide	28					✓	✓	✓					✓
Boric Acid	Boric Acid	UC			✓									
Brigade	Bifenthrin	3A	✓	✓			✓		✓		✓			
Centaur	Buprofezin	16								✓				
Clinch	Abamectin	6			✓									
Danitol	Fenpropathrin	3A					✓							
Delegate	Spinetoram	5					✓	✓	✓					✓
Diazinon	Diazinon	1B				✓								
Dimilin	Diflubenzuron	15							✓					

✓ = Use identified by Crop Team

Appendix 4. Pest by Active Ingredient for Almonds (Continued)

Product			Key Pests, No or Few Alternative AIs or Practices Available		Important Pests with Alternative AIs or Practices Available						Occasional Pests or Pests with Alternative AIs or Practices Available			
Trade Name(s)	Active Ingredient	IRAC MOA	Leaffooted Bug	Stink Bugs	Ants - Protein feeding	European Fruit Lecanium	Navel Orange-worm	Oriental Fruit Moth	Peach Twig Borer	San Jose Scale	Tree Borers (Prune Limb, American Plum)	Ten-lined beetle	Fuller rose beetle	Leaf rollers
Esteem Ant Bait	Pyriproxyfen	7C			✓									
Extinguish	Methoprene	7A			✓									
Imidan	Phosmet	1B					✓							
Intrepid	Methoxyfenozide	18					✓	✓	✓					✓
Lorsban Advanced	Chlorpyrifos	1B	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Narrow Range Oil	Narrow Range Oil	UC				✓				✓				
Proclaim	Emamectin Benzoate	6					✓		✓					✓
Seduce (bait)	Spinosad	5			✓									
Seize	Pyriproxyfen	7C								✓				
Sevin	Carbaryl (Sevin)	1B									✓			
Success, Entrust	Spinosad	5					✓	✓	✓					✓
Supracide	Methidathion	1B								✓				
Tourismo (pre mix)	Buprofezin Flubendiamide	Mix 16,28								✓				
Warrior	Lambda - cyhalothrin	3A	✓	✓			✓		✓		✓			
Xentari, Dipel	*Bacillus thuringiensis*	11B					✓	✓	✓					✓

✓ = Use identified by Crop Team

Appendix 5. Pest by Active Ingredient for Citrus

Product			Key Pests, No or Few Alternative AIs or Practices Available	Important Pests with Alternative AIs or Practices Available											Occasional Pests or Pests with Alternative AIs or Practices Available
Trade Name(s)	Active Ingredient	IRAC MOA	Ants	Asian Citrus Psyllid	Black Scale	Broad Mite	California Red Scale	Citricola Scale	Citrus Bud Mite	Citrus leafminer	Citrus Rust Mite (Silver Mite)	Fuller rose beetle	Katydids	Mealy bugs	*None noted by Crop Team. Pests considered too occasional or localized.*
Actara	Thiamethoxam	4A		✓											
Admire Pro	Imidacloprid	4A		✓		✓	✓			✓					
Agir-Mek, ABBA	Abamectin	6		✓		✓			✓	✓	✓				
Altaclor	Chlorantraniliprole	28		✓						✓					
Altrevin	Metaflumizone	22	✓												
Assail	Acetamiprid	4A					✓	✓		✓					
Bacillus thuringiensis	Dipel ES	11 B2													
Baythroid	Beta-cyfluthrin	3A		✓								✓			
Brigade	Bifenthrin	3A										✓			
Centaur	Buprofezin	16					✓								
Clinch	Abamectin	6	✓												
Danitol	Fenpropathrin	3A		✓											
Delegate	Spinetoram	5		✓											
Dibrom	Naled	1B													
Dicofol	Dicofol	UC				✓			✓						
Dimethoate	Dimethoate	1B		✓											

✓ **= Use identified by Crop Team**

Appendix 5. Pest by Active Ingredient for Citrus (Continued)

Product			Key Pests, No or Few Alternative Als or Practices Available	Important Pests with Alternative Als or Practices Available											Occasional Pests or Pests with Alternative Als or Practices Available
Trade Name(s)	Active Ingredient	IRAC MOA	Ants	Asian Citrus Psyllid	Black Scale	Broad Mite	California Red Scale	Citricola Scale	Citrus Bud Mite	Citrus leafminer	Citrus Rust Mite (Silver Mite)	Fuller rose beetle	Katydids	Mealy bugs	*None noted by Crop Team. Pests considered too occasional or localized.*
Endivor	Sprirodiclofen	23				✓			✓						
Entrust	Spinosad	5		✓											
Envidor	Spriodiclofen	23									✓				
Esteem ant bait	Pyriproxyfen	3A	✓												
Fujimite	Fenproximate	21A		✓		✓					✓				
Grandevo	Chromobacterium Subtsugae Strain	UC		✓											
Kryocide	Cryolite	9A										✓	✓		
Lannate	Methomyl	1A													
Leverage Premix	Beta-cyfluthrin Imidacloprid 4A	Mixed 3A, 4a		✓											
Lorsban 4E	Chlorpyrifos 4EC	1B	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	
Lorsban 75G	Chlorpyrifos 75% wettable granule	1B	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	
Lorsban Advanced (low VOC)	Chlorpyrifos 3.75 EC	1B	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	
Malathion	Malathion	1B					✓	✓							

✓ = **Use identified by Crop Team**

Appendix 5. Pest by Active Ingredient for Citrus (Continued)

Product			Key Pests, No or Few Alternative AIs or Practices Available	Important Pests with Alternative AIs or Practices Available											Occasional Pests or Pests with Alternative AIs or Practices Available
Trade Name(s)	Active Ingredient	IRAC MOA	Ants	Asian Citrus Psyllid	Black Scale	Broad Mite	California Red Scale	Citricola Scale	Citrus Bud Mite	Citrus leafminer	Citrus Rust Mite (Silver Mite)	Fuller rose beetle	Katydids	Mealy bugs	*None noted by Crop Team. Pests considered too occasional or localized.*
Micromite	Diflubenzuron	15		✓		✓				✓					
Movento	Spirotetramat	23		✓	✓										
Mustang	Zeta-cypermerthin	3A		✓											
Narrow Range Oil	Narrow Range Oil	UC		✓	✓		✓	✓	✓	✓					
Neemix	Azadirachtin	UC		✓						✓					
Platinum	Thiamethoxam	4A								✓					
Pyganic	Pyrethrin	3A		✓											
Sevin	Carbaryl	1A		✓	✓		✓	✓				✓			
Seize	Pyriproxyfen	7C													
Sulfur - micronized WP	Sulfur	UC				✓									
Sulfur wettable powder	Sulfur	UC													
Supracide	Methidathion	1B						✓							
Vendex	Fenbutatin Oxide	12B							✓						

✓ = Use identified by Crop Team

Appendix 6. Pest by Active Ingredient for Cotton

Product			Key Pests, No or Few Alternative AIs or Practices Available		Important Pests with Alternative AIs or Practices Available			Occasional Pests or Pests with Alternative AIs or Practices Available				
Trade Name(s)	Active Ingredient	IRAC MOA	Late Season Cotton Aphid	Sweetpotato Whitefly (Late Season)	Brown Stinkbug	Early to Mid Season Cotton Aphid	*Lygus*	Beet Armyworm	Cutworms	Pink Bollworm	Seedcorn Maggot	Wireworms
Admire Flowable	Imidacloprid	4A				✓						
Asana	Esfenvalerate	3A						✓		✓		
Assail	Acetamiprid	4A				✓						
Baythroid	Beta-cyfluthrin	3A					✓					
Belay	Clothiandin	4A					✓					
Belt	Flubendiamide	28						✓				
Capture	Bifenthrin	3A		✓			✓	✓				
Carbine	Flonicamid	9C				✓	✓					
Centric	Thiamethoxam	4A				✓						
Coragen	Chlorantraniliprole	28						✓				
Courier	Buprofezin	16		✓								
Cruiser	Thiamethoxam	4A				✓						
Cypermethrin	Cypermethrin	3A								✓		
Danitol	Fenpropathrin	3A		✓								
Diamond, Mayhem	Novaluron	15					✓	✓				
Dimethoate, many generics	Dimethoate	1B					✓					
Dimilin	Diflubenzuron	15						✓				

✓ = **Use identified by Crop Team**

Appendix 6. Pest by Active Ingredient for Cotton (Continued)

Product			Key Pests, No or Few Alternative AIs or Practices Available		Important Pests with Alternative AIs or Practices Available			Occasional Pests or Pests with Alternative AIs or Practices Available				
Trade Name(s)	Active Ingredient	IRAC MOA	Late Season Cotton Aphid	Sweetpotato Whitefly (Late Season)	Brown Stinkbug	Early to Mid Season Cotton Aphid	*Lygus*	Beet Armyworm	Cutworms	Pink Bollworm	Seedcorn Maggot	Wireworms
Fulfill	Pymetrozine	9B				✓						
Gaucho	Imidacloprid	4A				✓						
Insecticidal Soap UC	Insecticidal Soap	UC				✓		-				
Intrepid	Methoxyfenozide	18		✓				✓				
Knack	Pyriproxyfen	7C										
Lannate	Methomyl	1A				✓		✓				
Larvin	Thiodicarb	1A						✓				
Leverage (Pre-mix)	Beta-cyfluthrin Imidacloprid	3A 4A					✓					
MSR	Oxydemeton-Methyl	1B				✓						
Lorsban 4E and generics	Chlorpyrifos	1B	✓	✓		✓	✓	✓	✓	✓		
Lorsban Advanced and generics	Chlorpyrifos	1B	✓	✓		✓	✓	✓	✓	✓		
Narrow Range Oil UC	Narrow Range Oil	UC				✓						
Neemix	Azadirachtin	UC				✓						
Oberon	Spiromesifen	23		✓								
Orthene	Acephate	1B		✓			✓					

✓ = Use identified by Crop Team

Appendix 6. Pest by Active Ingredient for Cotton (Continued)

Product			Key Pests, No or Few Alternative AIs or Practices Available		Important Pests with Alternative AI or Practices Available			Occasional Pests or Pests with Alternative AIs or Practices Available				
Trade Name(s)	Active Ingredient	IRAC MOA	Late Season Cotton Aphid	Sweetpotato Whitefly (Late Season)	Brown Stinkbug	Early to Mid Season Cotton Aphid	*Lygus*	Beet Armyworm	Cutworms	Pink Bollworm	Seedcorn Maggot	Wireworms
Orthene as seed treatment	Acephate	1B							✓		✓	
Thimet	Phorate	1B				✓						
Provado and generics	Imidacloprid	4A										
Steward	Indoxacarb	22A					✓		✓	✓		
Success	Spinosad	5						✓		✓		
Venom	Dinotefuran	4A		✓								
Vydate	Oxamyl	1A		✓		✓	✓	-				
Warrior and generics	Lambda-cyhalothrin	1A					✓					

✓ = Use identified by Crop Team

Appendix 7. Example Relative Cost Ratio Calculation

The Relative Cost Ratio is a metric to standardize the difference in costs between alternative AIs and chlorpyrifos on a dollar per acre basis, excluding application costs.

An example calculation is provided below to show how the “Relative Cost Ratio” was determined.

Step 1. Collect product cost information and determine common unit cost.

Product 1	Product price	Volume (pint)	Common Unit Cost (fl oz)
Distributor 1	$ 10.00	1	$ 0.63
Distributor 2	$ 12.00	1	$ 0.75
Distributor 3	$ 9.00	1	$ 0.56

Step 2. Determine cost per acre based on low and high field rates and common unit cost for a Product 1

Product 1	$ 0.65	Avg Common Unit Cost
	$ 5.20	Low rate .5 Pt/Ac
	$ 15.60	High rate 1.5 Pt/Ac
	$ 10.40	Average Cost/Ac

Step 3. Determine cost per acre based on low and high field rates and common unit cost for chlorpyrifos

Chlorpyrifos	$ 0.35	Avg Common Unit Cost
	$ 2.80	Low rate .5 Pt/Ac
	$ 4.20	High rate .75 Pt/Ac
	$ 3.50	Average Cost/Ac

Step 4. Determine Relative Cost Ratio by dividing average cost/acre of Product 1 by average cost/acre for chlorpyrifos

Relative Cost Ratio	2.97

Step 5. Repeat for all products identified by crop team

Relative Cost	Trade Name(s)	Avg Common Unit Cost	Rates/Acre	Cost/Acre Low Rate	Cost/Acre High Rate	Average Cost/Ac
2.97	Product 1	$ 0.65	.5 -1.5 pt/Ac	$ 5.20	$ 15.60	$ 10.40
17.12	Product 2	$ 0.25	7.5-7.5 qt	$ 60.00	$ 60.00	$ 60.00
2.26	Product 3	$ 0.33	1 - 2 pts	$ 5.28	$ 10.56	$ 7.92
4.06	Product 4	$ 0.06	1.5-2 gal	$ 12.20	$ 16.27	$ 14.23
1.00	Chlorpyrifos	$ 0.35	.5 -.75 pt	$ 2.80	$ 4.20	$ 3.50

Appendix 8. CDPR Pesticide Use Data 2002-2012: Lbs of Chlorpyrifos Used in Alfalfa

Year	Lbs. AI	Acres Treated[1]	Acres[2]	% Acres Treated[3]	# Applications[4]	Lbs. AI per Acre[5]
2002	188,995	401,531	1,160,000	35%	6,356	0.47
2003	252,128	540,581	1,090,000	50%	7,935	0.47
2004	177,316	378,147	1,050,000	36%	5,477	0.47
2005	262,547	547,172	1,040,000	53%	8,586	0.48
2006	219,628	443,628	1,050,000	42%	6,887	0.50
2007	189,491	386,498	1,015,000	38%	6,107	0.49
2008	187,505	397,379	1,050,000	38%	6,235	0.47
2009	171,452	317,289	1,020,000	31%	5,280	0.54
2010	175,834	378,316	960,000	39%	6,185	0.46
2011	185,879	415,471	880,000	47%	6,700	0.45
2012	174,669	405,521	950,000	43%	6,397	0.43
Mean	198,677	419,230	1,024,091	41%	6,559	0.47

Appendix 9. CDPR Pesticide Use Data 2002-2012: Lbs of Chlorpyrifos Used in Almonds

Year	Lbs. AI	Acres Treated[1]	Acres[2]	% Acres Treated[3]	# Applications[4]	Lbs. AI per Acre[5]
2002	156,843	92,361	610,000	15%	1,646	1.70
2003	203,041	120,255	610,000	20%	2,036	1.69
2004	278,407	153,321	640,000	24%	2,524	1.82
2005	277,817	155,355	700,000	22%	2,479	1.79
2006	544,946	293,689	755,000	39%	3,928	1.86
2007	419,377	227,409	765,000	30%	2,684	1.84
2008	288,582	157,563	795,000	20%	266	1.83
2009	330,409	135,028	810,000	17%	3,543	2.45
2010	262,002	142,699	825,000	17%	2,004	1.84
2011	231,067	128,412	835,000	15%	1,527	1.80
2012	192,482	106,772	870,000	12%	1,622	1.80
Mean	289,543	155,715	746,818	21%	2,205	1.86

[1]Total acres receiving application.
[2]Total acres planted in California.
[3]Lbs AI/Acres
[4]Number of records from PUR
[5]Lbs AI/Acres treated

Appendix 10. CDPR Pesticide Use Data 2002-2012: Lbs of Chlorpyrifos Used in Citrus

Year	Lbs. AI	Acres Treated[1]	Acres[2]	% Acres Treated[3]	# Applications[4]	Lbs. AI per Acre[5]
2002	222,071	90,028	283,464	32%	3,744	2.47
2003	135,566	69,378	272,000	26%	3,087	1.95
2004	383,160	130,712	278,435	47%	5,330	2.93
2005	391,946	127,316	279,393	46%	5,076	3.08
2006	265,210	99,350	263,000	38%	4,053	2.67
2007	169,836	64,481	266,600	24%	2,775	2.63
2008	190,295	62,070	285,059	22%	2,720	3.07
2009	171,059	67,962	269,600	25%	2,846	2.52
2010	234,882	85,964	268,600	32%	3,295	2.73
2011	257,852	96,420	267,400	36%	3,737	2.67
2012	173,032	65,912	269,400	24%	2,936	2.63
Mean	235,901	87,236	272,996	32%	3,600	2.70

Appendix 11. CDPR Pesticide Use Data 2002-2012: Lbs of Chlorpyrifos Used in Cotton

Year	Lbs. AI	Acres Treated[1]	Acres[2]	% Acres Treated[3]	# Applications[4]	Lbs. AI per Acre[5]
2002	222,042	245,178	686,000	36%	2270	0.91
2003	278,851	313,248	694,000	45%	3007	0.89
2004	202,693	223,129	771,000	29%	1924	0.91
2005	349,170	390,194	657,000	59%	3127	0.89
2006	95,916	100,768	557,000	18%	794	0.95
2007	192,278	202,944	455,000	45%	1654	0.95
2008	68,352	74,817	285,000	26%	630	0.91
2009	36,691	39,931	186,000	21%	305	0.92
2010	115,024	125,865	303,000	42%	898	0.91
2011	194,173	206,923	454,000	46%	1568	0.94
2012	97,769	107,052	365,000	29%	828	0.91
Mean	168,451	184,550	492,091	36%	1,546	0.91

[1]Total acres receiving application.
[2]Total acres planted in California.
[3]Lbs AI/Acres
[4]Number of records from PUR
[5]Lbs AI/Acres treated