Title
Use and Benefits of Chlorpyrifos in Agriculture

Data Requirements
None

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Note to Reviewer: In this document, the following pesticide and trait names may be used interchangeably.

Table 1. Pesticide and Trait Names Referenced in this Document.

Pesticides and Traits		
Active Ingredient(s) Name	**Brand Name**	**Registered Trademark**
Abamectin	Agri-Mek®	Agri-Mek is a registered trademark of Syngenta Crop Protection LLC
Acephate	Orthene®, others	Orthene is a registered trademark of Venom is a registered trademark of Valent U.S.A. Corporation Agricultural Products
Acetamiprid	Assail®	Assail is a registered trademark of Nippon Soda Co., Ltd.
Azadirachtin	Neem Oil, several	---
Bacillus thuringiensis (Bt)	Several	---
Bifenthrin	Brigade®, Capture®, others	Brigade and Capture are registered trademarks of FMC Corporation Agricultural Products Group
Bifenthrin + Imidacloprid	Brigadier®	Brigadier is a registered trademark of FMC Corporation Agricultural Products Group
Bifenthrin+ Zeta-Cypermethrin	Hero®	Hero is a registered trademark of FMC Corporation Agricultural Products Group
Burholderia species cells	Venerate™ XC	Venerate XC is a registered trademark of Marrone Bio Innovations
Buprofezin	Applaud®, Centaur®, Courier®	Applaud, Centaur and Courier are a registered trademarks of Nichino America, Inc.
Buprofezin + flubendiamide	Vetica®	Vetica is a registered trademark of Nichino America, Inc.
Carbaryl	Sevin®	Sevin is a registered trademark of Bayer CropScience
Chlorantraniliprole	Altacor®, Coragen®, Prevathon®	Altacor, Coragen, and Prevathon are registered trademarks of E.I. DuPont de Nemours and Company
Chlorantraniliprole + Lambda-Cyhalothrin	Besiege®	Besiege is a registered trademark of Syngenta Crop Protection, LLC
Chlorpyrifos	Lock-On®, Lorsban®, others	Lorsban and Lock-On are registered trademarks of The Dow Chemical Company ("Dow") or an affiliated company of Dow
Chlorpyrifos + Gamma-Cyhalothrin	Cobalt®	Cobalt is a registered trademark of The Dow Chemical Company ("Dow") or an affiliated company of Dow
Chlorpyrifos + Lambda-Cyhalothrin	Cobalt® Advanced	Cobalt is a registered trademark of The Dow Chemical Company ("Dow") or an affiliated company of Dow

Pesticides and Traits		
Active Ingredient(s) Name	**Brand Name**	**Registered Trademark**
Chromobacterium subtsugae	Grandevo®	Grandevo is a registered trademark of Marrone Bio Innovations
Clothianidin	Belay®	Belay is a registered trademark of Valent U.S.A. Corporation Agricultural Products
Clothianidin + Imidacloprid	Sepresto®	Sepresto is a registered trademark of Bayer CropScience
Cyazypyr (cyantraniliprole)	Exirel®, Verimark™	Exirel and Verimark are registered trademarks of E.I. DuPont de Nemours and Company
Cyfluthrin	Baythroid®, others	Baythroid is a registered trademark of Bayer CropScience
Cyfluthrin + Imidacloprid	Leverage®	Leverage is a registered trademark of Bayer CropScience
Cyromazine	Trigard®	Trigard is a registered trademark of Syngenta Crop Protection LLC
Diazinon	Several	---
Dicrotophos	Bidrin®, others	Bidrin is a registered trademark of Amvac Chemical Corporation
Dimethoate	Several	---
Dinotefuran	Scorpion®, Venom®	Scorpion is a registered trademark of Gowan Company. Venom is a registered trademark of Valent U.S.A. Corporation
Emamectin benzoate	Proclaim®	Proclaim is a registered trademark of Syngenta Crop Protection LLC
Endosulfan	Portal®, Thionex®	Portal is a registered trademark of Nichino America, Inc. Thionex is a registered trademark of Makhteshim Agan of North America, Inc.
Ethoprop	Mocap®	Mocap is a registered trademark of Amvac Chemical Corporation
Esfenvalerate	Asana®	Asana is a registered trademark of E.I. DuPont de Nemours and Company
Fenpropathrin	Danitol®	Danitol is a registered trademark of Valent U.S.A. Corporation Agricultural Products
Flonicamid	Beleaf®, Carbine®	Beleaf and Carbine are registered trademarks of FMC Corporation Agricultural Products Group
Flubendiamide	Belt®	Belt is a registered trademark of Bayer CropScience
Flupyradifurone	Sivanto™	Sivanto is a registered trademark of Bayer CropScience
Gamma-Cyhalothrin	Proaxis™, others	Proaxis is a registered trademark of Loveland Products, Inc.
Imidacloprid	Admire®, Nuprid®, others	Admire is a registered trademark of Bayer CropScience. Nuprid is a registered trademark

Pesticides and Traits		
Active Ingredient(s) Name	**Brand Name**	**Registered Trademark**
		of Nufarm Americas Inc.
Indoxacarb	Avaunt®	Avaunt is a registered trademark of E.I. DuPont de Nemours and Company
Lambda-cyhalothrin	Karate®, Warrior®	Karate and Warrior are registered trademarks of Syngenta Crop Protection LLC
Lambda-cyhalothrin + Thiamethoxam	Endigo®	Endigo is a registered trademark of Syngenta Crop Protection, LLC
Malathion	Several	---
Methidathion	Supracide®	Supracide is a registered trademark of Gowan Company
Methomyl	Lannate®	Lannate is a registered trademark of E.I. DuPont de Nemours and Company
Methoxyfenozide	Intrepid®	Intrepid is a registered trademark of The Dow Chemical Company ("Dow") or an affiliated company of Dow
Oxamyl	Vydate®	Vydate is a registered trademark of E.I. DuPont de Nemours and Company
Permethrin	Ambush®, Pounce®, others	Pounce is a registered trademark of FMC Corporation Agricultural Products Group Ambush is a registered trademark of Amvac Chemical Corporation
Petroleum/Horticultural Mineral Oil	Several	---
Phorate	Thimet®, others	Thimet is a registered trademark of Amvac Chemical Corporation
Phosmet	Imidan®	Imidan is a registered trademark of Gowan Company
Pymetrozine	Fulfill®	Fulfill is a registered trademark of Syngenta Crop Protection LLC
Pyriproxyfen	Seize™, Esteem®, Knack®	Knack, Seize, and Esteem are registered trademarks of Valent U.S.A. Corporation Agriicultural Products
Spinetoram	Delegate®, Radiant®	Delegate and Radiant is a registered trademark of The Dow Chemical Company ("Dow") or an affiliated company of Dow
Spinosad	Entrust®, Naturalyte®	Entrust and Naturalyte are registered trademarks of The Dow Chemical Company ("Dow") or an affiliated company of Dow
Spiromesifen	Oberon®	Oberon is a registered trademark of Bayer CropScience
Spirotetramat	Movento®	Movento is a registered trademark of Bayer CropScience
Sulfoxaflor	Closer®, Sequoia®	Closer and Sequoia are registered trademarks of

Pesticides and Traits		
Active Ingredient(s) Name	**Brand Name**	**Registered Trademark**
		The Dow Chemical Company ("Dow") or an affiliated company of Dow
Terbufos	Counter®	Counter is a registered trademark of Amvac Chemical Corporation
Thiacloprid	Calypso®	Calypso is a registered trademark of Bayer CropScience
Thiamethoxam	Actara®, Cruiser®, FarMore®, Platinum®	Actara, Cruiser, FarMore, and Platinum are all registered trademarks of Syngenta Crop Protection, LLC
Zeta-Cypermethrin	Mustang® Maxx, others	Mustang Mass is a registered trademark of FMC Corporation Agricultural Products Group

Note to Reviewer: In this document, the following weed names may be used interchangeably.

Table 2, Common and Scientific Names of Insects Referenced in this Document.

Insects	
Common Name	**Scientific Name**
Alfalfa looper	*Autographa californica*
Alfalfa weevil	*Hypera postica*
American Plum Borer	*Euzophera semifuneralis*
Ants	Various species
Apple maggot	*Rhagoletis pomonella*
Aphid	Various species
Argus tortoise beetle	*Chelymorpha cassidea*
Army cutworm	*Euxoa auxiliaries*
Armyworms	*Pseudaletia unipuncta, Spodoptera* spp.
Artichoke plume moth	*Platyptilia carduidactyla*
Asian citrus psyllid	*Diaphorina citri*
Asparagus Aphid	*Brachycorynella asparagi*
Asparagus Beetle	*Crioceris asparagi*
Avocado leafroller	*Amorbia cuneana*
Bagworm	*Thyridopteryx ephemeraeformis*
Banded sunflower moth	*Cochylis hospes*
Bean leaf beetle	*Cerotoma trifurcate*
Bean seed maggot	*Hylemya florilega*
Beet armyworm	*Spodoptera exigua*
Bertha armyworm	*Mamestra configurata*
Billbugs	*Sphenophorus spp.*
Bird cherry-oat aphid	*Rhopalosiphum padi*
Black bean aphid	*Aphis fabae*
Black cutworm	*Agrotis ipsilon*
Blackheaded Fireworm	*Rhopobota naevana*
Black pecan aphid	*Melanocallis caryaefoliae*
Black twig borer	*Xylosandrus compactus*
Black vine weevil	*Otiorhynchus sulcatus*
Blue alfalfa aphid	*Acyrthosiphon kondoi*
Brown stink bug	*Euschistus servus*
Brown wheat mite	*Petrobia lateens*
Bruce Spanworm	*Operophtera bruceata*
Cabbage looper	*Trichoplusia ni*
Cabbage maggot	*Hylemya brassicae*
Codling moth	*Cydia pomonella*
Cereal leaf beetle	*Oulema melanopus*
Cherry fruit fly	*Rhagoletis cingulata*
Cherry fruitworm	*Grapholitha packardii*
Citricola scale	*Coccus pseudomagnoliarum*
Citrus leaf miner	*Phyllocnistis citrella*
Citrus peelminer	*Scirtothrips citri*
Citrus thrips	*Marmara gulosa*

Insects	
Common Name	**Scientific Name**
Citrus rust mite	*Phyllocoptruta oleivora*
Common stalk borer	*Papaipema nebris*
Codling moth	*Cydia pomonella*
Colorado potato beetle	*Leptinotarsa decemlineata*
Corn earworm	*Helicoverpa zea*
Corn root webworm	*Neodactria caliginosellus*
Corn rootworm	*Diabrotica virgifera*
Cornsilk fly	*Euxesta stigmatias*
Cotton aphid	*Aphis gossypii*
Cotton bollworm	*Helicoverpa zea*
Cranberry girdler	*Chrysoteuchia topiaria*
Cranberry fruitworm	*Acrobasis vaccinii*
Cranberry tipworm	*Dasineura oxycoccana*
Cranberry Weevil	*Anthonomus musculus*
Cucumber beetle	*Diabrotica undecimpunctata*
Currant fruitfly	*Epochra Canadensis*
Cutworms	*Agrotis spp.*
Diamondback moth	*Plutella xylostella*
Dipteran leafminers	*Liriomyza spp.*
Elm Spanworm	*Ennomos subsignaria*
European corn borer	*Ostrinia nubilalis*
European pine sawfly	*Neodiprion sertifer*
European red mite	*Panonychus ulmi*
Fall armyworm	*Spodoptera frugiperda*
Fall webworm	*Hyphantria cunea*
Filbert leafroller	*Archips rosana*
Filbert worm	*Melissapus latisferreana*
Fireworms	*Hermodice carunculata*
Fleabeetles	*Epitrix spp.*, others
Fruittree leafroller	*Archips argyrospilus*
Garden symphlyan	*Scutigerella immaculata*
Grape leafhopper	*Erythroneura* spp.
Grape leaf skeletonizer	*Harrisinia brillians*
Grape leaffolder	*Desmia funeralis*
Grape mealybug	*Pseudococcus maritimus*
Grasshoppers	*Melanoplus spp.*
Gray sunflower seed weevil	*Smicronyx sordidus*
Greater peachtree borer	*Synathedon exitiosa*
Green fruitworm	*Lithophane antennata*
Green stinkbug	*Acrosternum hilare*
Gypsy moth	*Lymantria dispar*
Hemlock looper	*Lambdina fiscellaria*
Hickory shuckworm	*Cydia caryana*
Hornworms	*Manduca spp.*
Imported cabbageworm	*Pieris rapae*
Japanese beetle	*Popillia japonica*
Katydids	*Tettigoniidae spp.*

Insects	
Common Name	**Scientific Name**
Lacanobia fruitworm	*Lacanobia subjuncta*
Liriomyza leafminers	*Liriomyza trifolii, L. huidobrensis, L. sativae*
Leafrollers	*Choristoneura spp.Pandemis spp., Archips spp.,* others
Lesser cornstalk borer	*Elasmopalpus lignosellus*
Lesser peachtree borer	*Synanthedon pictipes*
Loopers	*Trichoplusia spp,* others
Lygus bug	*Lygus spp.*
Mealybugs (pineapple)	*Dysmicoccus brevipes*, and *D. neobrevipes*
Melonworm	*Diaphania hyalinata*
Melon thrips	*Thrips palmi*
Mint cutworm	*Heliothis phloxiphaga*
Mint Root Borer	*Fumibotys fumalis*
Mites	Various species
Navel orangeworm	*Ameylois transitella*
Oblique banded leafroller	*Choristoneura rosaceana*
Omnivorous leafroller	*Platynota stultana*
Onion maggot	*Delia antiqua*
Onion thrips	*Thrips tabaci*
Orange tortrix	*Argyrotaenia citrana*
Orange wheat blossom midge	*Sitodiplosis mosellana*
Oriental fruit moth	*Grapholita molesta*
Pacific spider mite	*Tetranychus pacificus*
Pandemis leafroller	*Pandemis pyrusana*
Pea aphid	*Acyrthosiphon pisum*
Pecan weevil	*Curculio caryae*
Peach tree borer	*Synanthedon pictipes*
Peach twig borer	*Anarsia lineatella*
Pear psylla	*Cacopsylla pyricola*
Pear rust mite	*Epitrimerus pyri*
Pecan nut casebearer	*Acrobasis nuxvorella*
Pickleworm	*Diaphania nitidalis*
Pine tip moth	*Rhyacionia frustrana*
Plant bugs	Various species
Plum curculio	*Conotrachelus nenuphar*
Potato leafhopper	*Empoasca fabae*
Predatory midge	*Aphidoletes aphidimyza*
Range crane fly	*Tipula simplex*
Redbacked cutworm	*Euxoa ochrogaster*
Redbanded leafroller	*Argyrotaenia velutinana*
Redheaded pine sawfly	*Neodiprion lecontei*
Redhumped caterpillar	*Schizura concinna*
Red-banded leafroller	*Argyrotaenia velutinana*
(California) Red scale	*Aonidiella aurantii*
Red sunflower seed weevil	*Smicronyx fulvus*
Rice Stinkbug	*Oebalus pugnax*
Rindworms	*Diaphania hyalinata*

Insects	
Common Name	**Scientific Name**
Rosy apple aphid	*Dysaphis plantaginea*
San Jose scale	*Quadraspidiotus perniciosus*
Sawfly	Various species
Scales	Various species
Seed corn maggot	*Delia platura*
Silverleaf whitefly	*Bemisia argentifolii*
Sod webworm	*Crambus spp.*
Sorghum midge	*Contarinia sorghicola*
Sorghum webworm	*Nola sorghiella*
Southern Corn Rootworm	*Diabrotica undecimpunctata*
Southern armyworm	*Spodoptera eridania*
Southern potato wireworm	*Conoderus falli*
Southwestern corn borer	*Diatraea grandiosella*
Soybean aphid	*Aphis glycines*
Sparganothis fruitworm	*Sparganothis sulfureana*
Southern green stink bug	*Nezara viridula*
Spotted alfalfa aphid	*Therioaphis maculata*
Spotted cutworm	*Amathes c-nigrum*
Spotted fireworm	*Choristoneura parallela*
Spotted tentiform leafminer	*Phyllonorycter blancardella*
Spotted wing drosophila	*Drosophila Suzuki*
Springtails	*Collembola spp.*
Spruce budworm	*Choristoneura fumiferana*
Sweet potato flea beetle	*Chaetocnema confinis*
Sweet potato weevil	*Cylas formicarius elegantulus*
Sugarbeet root maggot	*Tetanops myopaeformis*
Sunflower beetle	*Zygogramma exclamationis*
Sunflower stem weevil	*Cylindrocopturus adspersus*
Tarnished plant bug	*Lygus lineolaris*
Tent caterpillar	*Malacosoma californicum pluviale*
Three-cornered alfalfa leaf hopper	*Spissistilus festinus*
Thrips	*Frankliniella spp, Thrips spp*, others
Tobacco aphid	*Myzus persicae*
Tobacco budworm	*Heliothis virescens*
Tobacco hornworm	*Manduca sexta*
Tobacco wireworm	*Conoderus vespertinus*
Tomato fruitworm	*Helicoverpa zea*
Tomato pinworm	*Keiferia lycopersicella*
Tufted apple budmoth	*Platynota idaeusalis*
Tussock moths	*Orgyia pseudotsugata*
Twospotted spider mite	*Tetranychus urticae*
Variegated cutworm	*Peridroma saucia*
Variegated leafroller	*Platynota flavedana*
Vine mealybug	*Planococcus ficus*
Walnut caterpillar	*Datana integerrima*
Walnut husk fly	*Rhagoletis completa*
Western bean cutworm	*Richia albicosta*

Insects	
Common Name	**Scientific Name**
Western cherry fruit fly	*Rhagoletis indifferens*
Western flower thrips	*Frankliniella occidentalis*
Western raspberry fruitworm	*Byturus bakeri*
Western tussock moth	*Orgyia vetusta*
Western Yellowstriped armyworm	*Spodopera praefica*
Wheat midge	*Sitodiplosis mosellana*
Wireworms	*Limonius spp.*
Whiteflies	*Trialeurodes vaporariorum, others*
White grubs (scarabs)	*Scarabaeidae*
White mold	Sclerotinia sclerotiorum
Worms	Various species
Yellowstriped armyworm	*Spodoptera ornithogalli*
Yellow pecan aphid	*Monelliopsis pecanis*

Note to Reviewer: The following abbreviations and definitions are implied in this document:

- **A** – abbreviation for "acre" and used as /A, to represent "per acre."
- **Active Ingredient** – The component which kills or otherwise controls or suppresses target pests. A pesticide product may contain one or more active ingredients, as well as one or more inert ingredients.
- **Active Ingredient Acres Treated** – Represents the cumulative acres treated with a single active ingredient. The same field can be treated more than once in a year with the same active ingredient. For products that contain more than one active ingredient, each ingredient is recorded separately as a single application to the same acres. For example, if a 20-acre field is treated with a product that contains three different pesticide active ingredients, a use report is filed by the farmer correctly recording the application of a single pesticide product to 20 acres. However, in the summary tables, the three different active ingredients will each have recorded 20 acres treated. Adding these values results in a total of 60 acres being treated instead of the 20 acres actually treated. Therefore, active ingredient acres treated will typically exceed the total number of acres actually treated.
- **a.i. – abbreviation for "active** ingredient."
- **CDPR** – abbreviation for California Department of Pesticide Regulation.
- **DAS** – abbreviation for Dow AgroSciences, LLC.
- **GPA** – abbreviation for "gallons per acre."
- **IPM** – integrated pest management.
- **IRM** – integrated resistance management.
- **Lb** – abbreviation for pound.
- **MOA** – abbreviation for mode of action.
- **NASS** – abbreviation for National Agricultural Statistics Service.
- **Number of Applications** – The total number of applications given for each crop may not equal the sum of all applications of each active ingredient on that crop. As explained above, some insecticide products contain more than one active ingredient.
- **Pest Acres** – Represents the cumulative acres treated with a single active ingredient for each target pest. The same field can be treated with one or more applications of an active ingredient to control multiple pests. For products that are used to control more than one pest, each target pest is recorded separately as a single application to the same acres. For example, if a **20-**acre field is treated once with a broad spectrum pest control product targeting two different pests, a use report is filed by the farmer correctly recoding the application of a single insecticide product to 20 acres. However, in the summary tables, the two different pests will each have recorded 20 acres treated. Adding these values results in a total of 40 acres being treated instead of the 20 acres actually treated. Therefore, pest acres will typically exceed both the total number of acres actually treated and the number of active ingredient treated acres.

- **USDA Farm Production Regions**

Atlantic States	Midwest	Plains States	West	South
Connecticut	Illinois	Kansas	Alaska	Alabama
Delaware	Indiana	Nebraska	Arizona	Arkansas
Maine	Iowa	North Dakota	California	Florida
Maryland	Michigan	Oklahoma	Colorado	Georgia
Massachusetts	Minnesota	South Dakota	Hawaii	Kentucky
New Hampshire	Missouri	Texas	Idaho	Louisiana
New Jersey	Ohio		Montana	Mississippi
New York	Wisconsin		Nevada	North Carolina
Pennsylvania			New Mexico	South Carolina
Rhode Island			Oregon	Tennessee
Vermont			Utah	Virginia
			Washington	West Virginia.
			Wyoming	

1. Executive Summary

This document is designed to provide specific evidence and documentation to support the position that chlorpyrifos provides significant and unique value to crop production in the U.S., and that the value created is sufficient to merit the continuation of all registered food crop uses. Dow AgroSciences is confident that a thorough examination of the information and data provided in this document will support this decision.

Chlorpyrifos is one of the most widely used active ingredients in insecticides in the world. Chlorpyrifos was first registered in the U.S. in 1965 and received its first crop use approvals in 1974. Products containing chlorpyrifos have been on the market for more than 40 years. Today, chlorpyrifos is registered in more than 98 countries worldwide for use on more than 50 different crops against damage caused by a wide range of insect pests.

Chlorpyrifos is an organophosphate insecticide (IRAC Group 1B MOA). Its insecticidal action is due to the inhibition of the enzyme acetylcholinesterase, resulting in the accumulation of the neurotransmitter, acetylcholine, at nerve endings. This results in excessive transmission of nerve impulses, which causes mortality in the target pest. Chlorpyrifos is effective primarily by contact, but it also has action through ingestion. It has generally exhibited short residual activity on plant foliage.

Chlorpyrifos contributes significantly to the control of insect pests in a wide range of corps including cereal, oil, forage, fruit, nut, and vegetable crops. The following are the multiple attributes of chlorpyrifos which meet a wide variety of important needs as reported by growers. In evaluating the need for chlorpyrifos and the potential impact of revoking tolerances and losing uses, a complete analysis should consider the list, and not just control of a primary pest.

Chlorpyrifos attributes:

- Reliable control of a broad spectrum of insect pests;
- Active on foliar-feeding and soil-dwelling insect pests;
- Fast knockdown;
- Significantly less disruptive to beneficial populations than some other insecticides and does not flare mites or aphids;
- Flexible application timing and method;
- Important tank mix partner for controlling tough pests;
- Good rotational partner to manage insect resistance;
- Easily implemented into existing IPM and IRM programs;
- Excellent safety on the crop;
- Broad label;
- International tolerances and maximum residue limits in place in export destination countries;
- Moderate mammalian toxicity;

- Easy to handle; and
- Strong technical support database.

The following provides a high-level summary of the assessment presented in this document grouped into five categories which demonstrate the unique value chlorpyrifos provides to the production of food crops in the U.S.

1.1 Chlorpyrifos was the insecticide most-used to control certain primary insect pests in a variety of crops

Insecticide use survey data from 2012-2014 was used to identify which insect pests were targeted in the crops chlorpyrifos is registered on, and what insecticides were used to control them. The analysis identified that chlorpyrifos was the leading insecticide active ingredient to control the following insects in the following crops:

- Aphids and armyworm in alfalfa;
- European asparagus aphid and other aphid species as well as cutworm in asparagus;
- Cabbage maggot in brassica vegetables;
- Leafroller in filberts;
- Corn rootworm and lesser cornstalk borer in peanut;
- San Jose scale in Washington state cherries, and American plum borer, and peachtree borer in Michigan cherries;
- Peach tree borer and lesser peach tree borer in peaches and nectarines. Also, the second most-used product for control of San Jose scale in peaches and nectarines;
- Wireworm in tobacco. Also, second most-used insecticide for cutworm in tobacco;
- Codling moth and walnut husk fly in walnuts;
- Pecan nut casebearer and black pecan aphid in pecans;.
- Wheat midge in wheat. Also the second leading insecticide active ingredient used to control aphids in wheat; and
- In apples in the Pacific Northwest for use as a dormant or delayed dormant treatment to control overwintering generations of a number of insect pests including oblique-banded and red-banded leafrollers, *Pandemis* leafrollers, and San Jose scale.

The diversity of insects listed above demonstrates the broad spectrum control offered by chlorpyrifos and its importance to insect management in a wide range of crops.

1.2 Chlorpyrifos is the only insecticide alternative available to control certain insect pests.

Few insecticide alternatives are available for the control of certain insect pests, especially for minor or new pests, or for use in small acreage crops. The broad spectrum control of chlorpyrifos makes it an ideal candidate for solving unique insect control problems. Following are examples of where chlorpyrifos has provided a solution:

- **Mealybug Control in Pineapple** – Chlorpyrifos is the only insecticide to directly control mealybug and reduce transmission of mealybug wilt disease in pineapple. Pineapple has relatively few insect pests, however, mealybugs and the ants which tend them are associated with the very serious mealybug wilt disease. Mealybug wilt can occur if mealybug populations become high. Entire fields, up to 50% of the plants in a field, can be lost if control is not undertaken. Most often the ants are controlled which allow natural predators to keep the mealybug population in check. A 24(c) Special Local Need label allows the use of chlorpyrifos (Lorsban Advanced) to control mealybug on nonbearing pineapple in Hawaii (24c SLN: HI-090001 [expires 9/30/19]). No other insecticides are registered for this use.
- **Garden Symphylan Control in Strawberry** – Garden symphylans damage strawberry plants by feeding on roots and retarding plant growth. They are usually only a problem in strawberry fields that were not fumigated, or if the fumigation was ineffective. Chlorpyrifos was used on all strawberry acres that were treated for garden symphylans in 2012-2014. Maintaining the availability of chlorpyrifos in the strawberry is important because there are few alternatives available to control this pest.
- **Cranefly Control in Cranberries** – Cranefly larvae, called leatherjackets, feed on roots and underground rhizomes of mint plants from the fall through spring months. Cranefly control is a unique benefit of chlorpyrifos. No insecticides are labeled for cranefly control, however, research and field use in Oregon indicate chlorpyrifos is effective against craneflies. Chlorpyrifos is not labeled for cranefly control in mint, but may be used because it is registered to control other pests on the crop.

Chlorpyrifos is often the first product growers use to attempt control of a new or unknown insect pest because of its broad spectrum control and effectiveness.

1.3 Chlorpyrifos provides broad spectrum control, and is an integral component of pest management programs in many crops

Chlorpyrifos has been an integral component of insect pest management programs for decades due to its efficacy, cost, broad spectrum control, and ease of implementation into existing IPM and IRM programs. Chlorpyrifos offers broad spectrum control of soil and foliar insect pests such as:

- Products containing chlorpyrifos are widely used in citrus for control of scale, mealybug, citrus rust mite, various Lepidoptera larvae, and ants. Since the introduction of the Asian citrus psylla to the continental U.S. in 1998, chlorpyrifos has been widely used to control this pest;
- Products containing chlorpyrifos are widely used and highly effective against the most important insect pests of alfalfa. These pests include alfalfa weevil, leafhoppers, aphids, and Lepidoptera pests;
- Chlorpyrifos offers broad spectrum control of numerous pest species in sugarbeets including aphids, root maggot, leafminer, and worms;

- Chlorpyrifos provides effective control of several primary insect pests in asparagus including European asparagus aphid and other aphid species, asparagus beetle, and cutworm as well as other economically important insect pests;
- Chlorpyrifos provides effective control of several of the primary insect pests in cotton including Lygus bug, plant bug, stink bug, silverleaf whitefly, and aphids as well as other economically important insect pests such as spider mites, armyworm and soybean looper;
- Dormant and delayed dormant applications of products containing chlorpyrifos in combination with petroleum oil spray have demonstrated excellent efficacy, and are widely used in commercial pome and stone fruit production. Pests controlled by chlorpyrifos include San Jose scale, peach twig borer, rosey apple aphid, pandemis and oblique-banded leafrollers, and climbing cutworms; and
- Products containing chlorpyrifos have been extensively utilized for the control of soil insect pests on peanuts in the U.S. Chlorpyrifos provides effective control of the primary insect pests in peanuts including corn rootworm, lesser cornstock borer and cutworms and protects against aflatoxin contamination and white mold infection by reducing insect injury.

These examples demonstrate the importance of chlorpyrifos to insect management programs in a broad range of crops. The loss of chlorpyrifos would result in greater use of pyrethroids in some crops or the use of more expensive alternatives. In some instances, the loss of chlorpyrifos would result in increased insecticide use where it was replaced by an insecticide with a less-broad spectrum of control. Additional insecticide applications may be required to control multiple pests if the alternative insecticide did not control all insect pests present, or damaged the natural beneficial population resulting in flaring of certain insect pest populations.

1.4 Chlorpyrifos is an important Integrated Pest Management (IPM) tool

Integrated Pest Management is a critical component of sustainable insect management programs. Chlorpyrifos offers a valuable tool for use in IPM and IRM programs because of the following characteristics:

- Group 1B MOA;
- Effective control;
- Relatively short persistence and short-term impact on natural enemy populations,
- Tank-mix flexibility allowing applicators to tailor mixtures to help manage resistance or control multiple insects;
- Foliar applied to insect stages recommended on the product label allowing for careful monitoring, diagnosis, and prescription insect control;
- Excellent crop safety promotes a healthy crop. A healthy crop is better equipped to recover from insect attack, resist diseases and out-compete weeds. Excellent crop safety allows application timing for optimum insect control without concern of crop injury; and

- A favorable environmental fate, toxicology, and ecotoxicology profiles ensures minimal impact to the environment and rotational crops.

Chlorpyrifos is significantly less disruptive to beneficial populations than some other insecticides and, when used as part of an IPM program, it has a short-term impact on natural enemy populations. Following is an example of chlorpyrifos use in citrus IPM programs:

- Chlorpyrifos is very important to IPM programs in citrus. Chlorpyrifos has minimal impact on the beneficial *Aphytis* wasp, which is important for late season biocontrol of California red scale populations. Control of scales in California citrus, especially oranges and lemons, is a high anxiety issue for producers. It has been documented that some insecticide alternatives to chlorpyrifos have a negative impact on the vedalia beetle, a beneficial predatory insect used as biological control to naturally regulate populations of cottony cushion scale in citrus. The vedalia beetle is very sensitive to cyfluthrin, an insecticide being used for citrus thrips control, and the insect growth regulators, pyriproxifen and buprofezin which are applied for California red scale control. Cyfluthrin kills the beetles and prevents them from laying eggs. The insect growth regulators prevent vedalia from pupating and emerging as adults, and in the case of buprofezin, they prevent the adults from laying fertile eggs.

1.5 Chlorpyrifos is an important Integrated Resistance Management (IRM) tool

The long-term success of chlorpyrifos as a resistance management tool will depend upon thoughtful implementation of effective IPM and IRM programs. Dow AgroSciences has worked closely with university entomologists to develop guidelines for chlorpyrifos use in existing IPM and IRM programs. Chlorpyrifos is an effective rotation partner to manage insect resistance. It offers a Group 1B mode of action to help manage resistance. Pyrethroids (Group 3A MOA) are used extensively in alfalfa, cotton, sorghum, soybeans, wheat, tree nuts and others crops because they are inexpensive, broad spectrum, and effective. Chlorpyrifos was the leading non-pyrethroid insecticide active ingredient in several of these crops. The availability of chlorpyrifos allows growers to rotate between different insecticide modes of action, which helps delay resistance development in all insecticides. Resistance development to pyrethroids and other insecticides would proceed at an accelerated rate in the absence of chlorpyrifos.

2. Introduction

2.1 Purpose of Analysis

Insect pests cause billions of dollars worth of damage and threaten our food supply, our property, our health, and the livelihood of growers. Insects have a remarkable ability to adapt to environmental pressures, to changes in cropping systems, cultural practices and climate, and to tolerate or resist management strategies, including insecticides. To protect our food supply and satisfy the needs of a growing population, growers need full access to a broad range of effective and sustainable insect management tools to manage insect infestations. Insecticides, such as chlorpyrifos, have played, and will continue to play, an important role in a sustainable insect management strategy.

"Insecticides enable U.S. farmers to produce and harvest greater marketable yields than would otherwise be possible. By mitigating the effects of crop-feeding insects, U.S. farmers produce 144 billion pounds of additional food, feed and fiber and reap $22.9 billion in farm income increases. Growers in California benefit the most from the use of insecticides ($7.5 billion/year), followed by [growers in the states of] Washington and Florida ($2.8 and $2.5 billion/year, respectively)....**Before the use of insecticides became widespread, insects consumed about 50% of the nation's crops**" [1].

A multi-year regulatory review of chlorpyrifos by the Environmental Protection Agency (EPA) known as Registration Review opened in early 2009. This report is a guide to growers, commodity groups, and regulatory decision-makers regarding the benefits of chlorpyrifos in U.S. agriculture. This report will provide the reader with the information and resources needed to answer questions regarding chlorpyrifos use on major crops throughout the U.S.

Chlorpyrifos products in the U.S. underwent a rigorous re-registration process that began in 1984 and concluded in 2006. This included evaluation for potential human health and environmental impacts as well as a cumulative consumer risk assessment for the organophosphate class of insecticides [2].

2.2 Scope and Approach

The scope of this analysis will attempt to identify potential national impacts on United States growers and society associated with the loss of the registered food crop uses and associated crop, processed fraction, animal feed and animal commodity tolerances for chlorpyrifos. This assessment provides background on the specific benefits of chlorpyrifos versus alternative insecticides, application methods, and available alternative control methods. The assessment was conducted using information from the National Agricultural Statistics Service, DAS, published literature, University Extension publications, and the Crop Profiles available from The National Information Center for the Regional IPM Centers.

2.3 Overview of Chlorpyrifos

Chlorpyrifos is one of the most widely used active ingredients in insecticides in the world. It is used to protect a number of important agricultural crops such as soybeans, wheat, alfalfa, citrus, tree nuts, peanuts, vegetables, and others from losses to insect pests. Chlorpyrifos was first registered in the U.S. in 1965 and received its first crop use approvals in 1974. Products containing chlorpyrifos have been on the market for more than 40 years [3]. Today, chlorpyrifos is registered in more than 98 countries worldwide for use on more than 50 different crops against damage caused by a wide range of insect pests.

Mode of Action
Chlorpyrifos is an organophosphate insecticide (IRAC Group 1B MOA). Its insecticidal action is due to the inhibition of the enzyme acetylcholinesterase, resulting in the accumulation of the neurotransmitter, acetylcholine, at nerve endings. This results in excessive transmission of nerve impulses, which causes mortality in the target pest.

Efficacy
Chlorpyrifos provides broad spectrum control of insect pests in cereal, oil, forage, fruit, nut, and vegetable crops. The efficacy of chlorpyrifos has been tested under both laboratory and field conditions using a variety of formulations. Chlorpyrifos is effective primarily by contact, but it also has action through ingestion. Chlorpyrifos has proven activity on a wide range of pests in a large number of crops worldwide. It has generally exhibited short residual activity on plant foliage.

Chlorpyrifos Attributes
The following are the multiple attributes of chlorpyrifos which meet a wide variety of important needs as reported by growers. In evaluating the need for chlorpyrifos and the potential impact of revoking tolerances and losing uses, a complete analysis needs to consider the list, and not just control of a primary pest.

- Broad spectrum insecticidal activity
- High efficacy
- Active on foliar-feeding and soil-dwelling insect pests
- Fast knockdown
- Significantly less disruptive to beneficial populations than some other insecticides and does not flare mites or aphids
- Flexible application timing and method
- Important tank mix partner for controlling tough pests
- Good rotational partner to manage insect resistance
- Broad label
- International tolerances and maximum residue limits in place in export destination countries
- Moderate mammalian toxicity

- Easy to handle
- Strong technical support database

Manufacturers

Dow AgroSciences LLC is the primary manufacturer of chlorpyrifos. Other companies in China, Denmark, India, and Israel also manufacture chlorpyrifos. For more information about chlorpyrifos, visit www.chlorpyrifos.com.

2.4 Chlorpyrifos Brand Names and Formulations

Chlorpyrifos is commercialized as a solvent-based emulsifiable concentrate (EC), water-based (EC, emulsion in water), granular (G), wettable granule (WG), and wettable powder (WP) formulations. It is available under several brand names.

Table 3. Chlorpyrifos Brands, Formulations, and Concentrations.

Brand Name	Formulation Type. EC = Emulsifiable Concentrate WG = Wettable Granule G = Granular WP = Wettable Powder	Concentration of Active Ingredient
Lorsban Advanced	EC[1]	3.755 lb a.i./gallon
Lorsban-4E Nufos 4E Yuma 4E Warhawk Govern 4E Chlorpyrifos 4E AG Whirlwind	EC	4.0 lb a.i./gallon
Cobalt	EC	2.5 lb a.i./gallon chlorpyrifos + 0.045 lb a.i./gallon gamma-cyhalothrin
Cobalt Advanced	EC	2.5 lb a.i./gallon chlorpyrifos + 0.129 lb a.i./gallon lambda-cyhalothrin
Lock-On	EC	2.0 lb a.i./gallon
Lorsban 15G	G	150 g/Kg (15%)
Lorsban 75WG	WG	750 g/Kg (75%)
Lorsban 50W in WSP Dursban 50W in WSP	WP	500 g/Kg (50%)

[1]Lorsban Advanced is a water-based emulsion, low volatile organic carbon solvent content

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2. Dow AgroSciences. Chlorpyrifos – North America. *Regulatory/EPA Registration Review*. http://www.chlorpyrifos.com/. Accessed December 16, 2015.
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3. Chlorpyrifos Use Analysis

Following is a comparison of chlorpyrifos use data from 2012-2014 and 2003-2007.

Table 4. Chlorpyrifos Crop Use Data – Lb. a.i. 2003-2007 and 2012-2014.

Major Crops	Annual Usage Lb a.i.					
	2012	2013	2014	2012-2014 Average[1]	2003-2007 Average[1]	Avg. 2012-2014 Use as a % of Avg. 2003-2007 Use
Alfalfa	763,633	532,706	747,805	681,381	374,750	182%
Almonds	256,220	566,656	289,663	370,846	530,702	70%
Apples	294,264	367,249	326,317	329,277	414,600	79%
Asparagus	20,210	19,612	19,924	19,915	22,104	90%
Beans (Snap, Bush, Pole, String)	3,929	4,788	2,112	3,610	3,295	110%
Broccoli	85,939	39,429	46,171	57,180	95,819	60%
Brussels Sprouts	--	--	--	--	--	--
Cabbage	13,676	1,365	3,421	6,154	18,127	34%
Carrots	--	--	--	--	--	--
Cauliflower	10,250	5,629	--	5,293	20,188	26%
Cherries	65,394	72,066	93,421	76,960	80,140	96%
Corn	795,268	712,380	402,920	636,856	2,617,433	24%
Cotton	84,106	120,978	111,668	105,584	161,692	65%
Cranberries	--	--	--	--	--	--
Dry Beans/Peas	9,568	8,289	848	6,235	2,427	257%
Fig	--	--	--	--	--	--
Grapefruit	41,974	56,510	130,533	76,339	54,855	139%

Major Crops	Annual Usage Lb a.i.					
	2012	2013	2014	2012-2014 Average[1]	2003-2007 Average[1]	Avg. 2012-2014 Use as a % of Avg. 2003-2007 Use
Grapes, Raisin	22,323	14,859	29,340	22,174	29,219	76%
Grapes, Table	38,033	32,505	59,824	43,454	93,358	47%
Grapes, Wine	18,969	9,864	22,822	17,218	63,571	27%
Hazelnuts	5,083	3,869	4,217	4,389	7,286	60%
Lemons	30,770	17,699	52,107	33,525	104,787	32%
Mint	--	--	--	--	--	--
Nectarines	--	--	--	--	--	--
Onions	56,413	64,610	43,526	54,850	68,805	80%
Oranges	374,335	447,781	282,221	368,112	486,830	76%
Peaches	34,701	52,921	28,114	38,579	79,380	49%
Peanuts	229,658	180,420	224,687	211,589	119,213	177%
Pears	13,508	7,520	20,789	13,939	29,564	47%
Peas (Fresh/Green/Sweet)	602	--	244	282	607	46%
Pecans	205,087	127,474	165,395	165,985	296,596	56%
Pineapple	--	--	--	--	--	--
Plums/Prunes	8,034	5,369	2,479	5,294	35,432	15%
Pumpkins	1,922	3,965	87	1,991	2,791	71%
Sorghum (Milo)	39,498	42,532	44,741	42,257	14,191	298%
Soybeans	1,435,982	1,073,324	1,158,698	1,222,668	814,361	150%
Strawberries	13,605	9,953	1,273	8,277	10,043	82%
Sugar Beets	192,546	240,270	113,008	181,941	138,020	132%
Sunflowers	66,678	47,551	91,209	68,479	34,857	196%
Sweet Corn	75,195	50,010	75,775	66,994	120,881	55%

Major Crops	Annual Usage Lb a.i.					
	2012	2013	2014	2012-2014 Average[1]	2003-2007 Average[1]	Avg. 2012-2014 Use as a % of Avg. 2003-2007 Use
Sweet Potatoes	--	--	--	--	--	--
Tangelos	--	--	--	--	--	--
Tangerines	--	--	--	--	--	--
Tobacco	49,264	16,282	68,614	44,720	98,468	45%
Walnuts	344,137	344,272	487,857	392,089	384,288	102%
Watermelons	2,183	51	41	758	616	123%
Wheat (Winter/Spring)	570,362	664,483	609,344	614,730	288,571	213%
Other	52,979	8,084	2,842	21,302	11,151	191%
Total	**6,324,115**	**5,973,274**	**5,764,015**	**6,020,468**	**7,728,540**	**78%**

Source: Proprietary third party data.
[1]Average annual use was calculated by dividing total lb a.i. used divided by 3 for 2012-2014 and by 5 for 2003-2007, regardless of whether or not chlorpyrifos was used every year.

4. Alfalfa

4.1 Overview

According to the U.S. Department of Agriculture (USDA), alfalfa is the fourth most widely grown crop in the U.S., with an estimated annual value of $10.8 billion in 2014. Alfalfa hay is primarily used as feed mostly for dairy cows, but also for horses, beef cattle, sheep, and other farm animals [1] [2]. More than 18 million acres of alfalfa were grown in the U.S. in 2014. Approximately 68% of planted alfalfa acres are in the West and Plains regions.

Table 5. U.S. Alfalfa Acres Harvested 2012–2014.

Region[1]	Area Harvested (000 acres)			
	2012	2013	2014	2012-2014 Average
Atlantic	820	770	660	750
Midwest	4,680	4,700	4,730	4,703
Plains	5,730	4,680	5,080	5,163
South	280	290	255	275
West	7,140	7,060	7,300	7,167
Total U.S.	**18,650**	**17,500**	**18,025**	**18,058**

Source: Proprietary third party data.
[1] USDA Farm Production Regions.

According to studies cited by CropLife Foundation, insecticide use in alfalfa varies by region: (numbers in these parentheses represent % acres treated) Northeast (48%), South (80%), North Central (14%), and West (33%) [2].

4.2 Chlorpyrifos Use

Chlorpyrifos was one of the two active ingredients most-used to control insect pests in alfalfa nationwide from 2012-2014, and was used on 24.8% of total active ingredient acres. Pyrethroids accounted for 56.2% of the active ingredient treated acres in 2012-2014. Chlorpyrifos was the most-used non-pyrethroid insecticide. Effective non-pyrethroid insecticides like chlorpyrifos are needed to help manage resistance development.

Table 6. Leading Insecticide Active Ingredients Used in Alfalfa – Acres Treated 2012–2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CYHALOTHRIN-LAMBDA	1,874,217	1,248,475	1,192,882	1,438,525	27.3%
CHLORPYRIFOS	1,329,533	1,137,898	1,457,616	1,308,349	24.8%
ZETA-CYPERMETHRIN	529,972	662,550	557,663	583,395	11.1%
CYFLUTHRIN	918,542	501,825	287,747	569,371	10.8%
INDOXACARB	130,802	270,054	352,308	251,055	4.8%
DIMETHOATE	194,963	208,286	283,912	229,054	4.3%
Total U.S.	**5,939,474**	**4,886,420**	**4,991,512**	**5,272,468**	**Column Total 83.1%**

Source: Proprietary third party data. Excluding seed treatments.

Growers used an average of 681,381 lb a.i. of chlorpyrifos annually to control insect pests in alfalfa in 2012-2014, an 82% increase in average annual use from 2003-2007 (374,750 lb a.i.).

Table 7. Chlorpyrifos Use in Alfalfa – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	1,329,533	1,137,898	1,457,616	1,308,349
Lb a.i. Applied	763,633	532,706	747,805	681,381

Source: Proprietary third party data. Excluding seed treatments.

The West and Plains regions accounted for 78% of all active ingredient acres in alfalfa in 2012-2014. Chlorpyrifos was the leading insecticide, and was used on over 28% of the active ingredient acres in these two regions.

Table 8. Leading Insecticide Active Ingredients Used in Alfalfa in the West and Plains Regions – Acres Treated 2012–2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CHLORPYRIFOS	1,117,634	1,000,469	1,392,883	1,170,329	28.5%
CYHALOTHRIN-LAMBDA	1,343,457	774,663	900,963	1,006,361	24.5%
ZETA-CYPERMETHRIN	379,573	489,288	386,365	418,409	10.2%
CYFLUTHRIN	621,743	232,786	153,926	336,152	8.2%
INDOXACARB	130,802	270,054	352,308	251,055	6.1%
DIMETHOATE	135,599	190,771	267,871	198,081	4.8%
Total West and Plains Regions	**4,609,642**	**3,599,515**	**4,120,755**	**4,109,971**	**Column Total 82.2%**

Source: Proprietary third party data. Excluding seed treatments.

Some variation in acres treated and lbs a.i. applied were found comparing CDPR and proprietary third party data for chlorpyrifos use in alfalfa.

Table 9. Chlorpyrifos Use in California Alfalfa – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	Data Source	2012	2013	2014	2012-2014 Average
Acres Treated	CDPR	401,906	432,947	463,053	432,635
	Proprietary third party	--	145,673	470,944	205,539
Lb a.i. Applied	CDPR	171,603	189,408	275,590	212,200
	Proprietary third party	--	65,682	251,693	105,792

4.3 Target Pests

Weevils, leafhoppers, aphids and armyworm are the primary insect pests of alfalfa, and account for 98% of total active ingredient acres. Each causes significant losses in alfalfa as described below. Chlorpyrifos provides broad spectrum control of a number of insect pests in alfalfa, and is among the leading active ingredients used to control these and other economically important insect pests of alfalfa.

Table 10. Top Insect Pests in Alfalfa – Acres Treated 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
WEEVIL, ALFALFA	3,276,738	2,077,093	2,045,572	2,466,468	46.8%
APHID	659,867	684,884	587,553	644,101	12.2%
LEAFHOPPER	684,731	786,187	339,237	603,385	11.4%
APHID, BLUE ALFALFA	453,118	425,407	746,411	541,646	10.3%
LEAFHOPPER, POTATO	362,030	350,124	305,936	339,363	6.4%
WEEVIL	238,002	425,309	245,664	302,992	5.7%
ARMYWORM	471,748	133,931	220,942	275,540	5.2%
U.S. Total	**7,674,358**	**6,549,336**	**6,152,638**	**6,792,111**	**Column Total 98.1%**

Source: Proprietary third party data. Excluding seed treatments.

4.3.1 Alfalfa Weevil

The alfalfa weevil is one of the primary insect defoliators of alfalfa. Insect pests of alfalfa, including the alfalfa weevil, cause hundreds of millions of dollars in losses annually. It is the target insect pest in 46.8% of the active ingredient acres applied nationally, and is an annual pest in districts east of the Sierra Nevada mountains and in the northernmost counties of California [4].

Young larvae damage alfalfa by feeding on terminal buds; larger larvae feed on the leaflets. Feeding by older larvae is the most damaging, and is characterized as skeletonization and bronzing of the leaves in spring. Under severe pressure, complete defoliation can occur [3].

Chlorpyrifos and lambda-cyhalothrin were the leading active ingredients used to control alfalfa weevil in 2012-2014. Chlorpyrifos was used on 26.7% of the acres treated to control weevils. The average cost of chlorpyrifos for weevil control was $5.07 per acre, nearly equal to the average cost of all insecticide active ingredients ($5.08 per acre) used to control weevils in 2014.

Table 11. Leading Insecticide Active Ingredients Used to Control Alfalfa Weevil and Egyptian Alfalfa Weevil in Alfalfa – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CYHALOTHRIN-LAMBDA	1,274,171	740,791	620,638	878,534	30.0%
CHLORPYRIFOS	937,672	604,527	810,633	784,277	26.7%
ZETA-CYPERMETHRIN	403,580	436,191	370,668	403,480	13.8%
CYFLUTHRIN	461,048	332,786	159,184	317,673	10.8%
INDOXACARB	44,159	224,981	293,326	187,489	6.4%
MALATHION	27,465	21,468	180,027	76,320	2.6%
U.S. Total	**3,528,135**	**2,562,013**	**2,706,558**	**2,932,235**	**Column Total 90.3%**

Source: Proprietary third party data. Excluding seed treatments.

4.3.2 Aphids

Several species of aphids infest alfalfa including the pea aphid, blue alfalfa aphid, and spotted alfalfa aphid. Aphids feed in groups, often on the growing tips of plants. They have piercing-sucking mouthparts that extract the plant sap (phloem). Excess plant sap is excreted as a sticky material called honeydew. Severe aphid infestations can retard growth, reduce hay yield, and may even kill alfalfa plants. Damage can also reduce the alfalfa's feed value. Furthermore, a black fungus called sooty mold, which grows readily on the honeydew excreted by aphids, reduces palatability of the alfalfa hay.

The pea aphid is the least serious pest of this complex, because it does not inject toxin into alfalfa plants as it feeds. Pea aphid damage is usually limited to cupping and curling of the leaves, and severe burning of the foliage when populations are large. Blue alfalfa and spotted alfalfa aphid inflict more serious damage because they inject toxins into the plant as they feed. Toxins injected by the blue alfalfa aphid can stunt growth and cause yellowing of the entire plant. Infested plants have smaller leaves and shorter internodes than normal. The spotted alfalfa aphid injects a toxin while feeding on the alfalfa plant which causes vein clearing, yellowing, and severe stunting of plant growth. Susceptible plants can be killed when populations are heavy. Alfalfa that is stressed by lack of water or by cutting is not able to withstand as large an aphid population as healthy unstressed alfalfa.

Chlorpyrifos was the leading active ingredient used to control aphids in alfalfa, and was used on 37.1% of the pest acres treated for aphids in 2012-2014. The average cost of chlorpyrifos for aphid control was $5.29 per acre, which was 10.0% less than the average cost of all insecticide active ingredients ($5.37 per acre) used to control aphids in 2014.

Table 12. Leading Insecticide Active Ingredients Used to Control Aphids in Alfalfa – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CHLORPYRIFOS	375,117	392,728	550,653	439,499	37.1%
CYHALOTHRIN-LAMBDA	199,673	151,778	265,936	205,796	17.4%
DIMETHOATE	74,838	132,806	153,125	120,256	10.1%
MALATHION	90,552	86,912	171,359	116,274	9.8%
ZETA-CYPERMETHRIN	43,298	187,145	110,202	113,548	9.6%
CYHALOTHRIN-GAMMA	193,466	9,017	--	67,494	5.7%
U.S. Total	**1,112,985**	**1,110,291**	**1,333,964**	**1,185,747**	**Column Total 89.6%**

Source: Proprietary third party data. Excluding seed treatments.

4.3.3 Armyworm

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. Chlorpyrifos was the leading active ingredient used to control armyworm, and was used on 24.7% of the pest acres treated for armyworm. The average price of chlorpyrifos for armyworm control was $6.11 per acre, which was 30% less than the average cost of all insecticide active ingredients ($8.76 per acre) used to control armyworm.

Table 13. Leading Insecticide Active Ingredients Used to Control Armyworm in Alfalfa – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CHLORPYRIFOS	152,663	11,649	40,240	68184	24.7%
CHLORANTRANILIPROLE	67,225	12,179	89,699	56367	20.5%
CYHALOTHRIN-GAMMA	140,274	--	12,586	50953	18.5%
CYHALOTHRIN-LAMBDA	63,633	15,776	--	26470	9.6%
FLUBENDIAMIDE	--	10,493	52,506	21000	7.6%
ZETA-CYPERMETHRIN	36,197	5,935	8,191	16774	6.1%
U.S. Total	**471,748**	**133,931**	**220,942**	**275540**	**Column Total 87.0%**

Source: Proprietary third party data. Excluding seed treatment.

4.3.4 Leafhoppers

Several species of leafhopper occur in alfalfa including the potato leafhopper and three-cornered alfalfa hopper. Leafhopper feeding causes yellow, wedge-shaped areas 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.

Chlorpyrifos is the third most-used active ingredient to control leafhoppers, and was used on 10.8% of the pest acres treated for this insect pest.

Table 14. Leading Insecticide Active Ingredients Used to Control Leafhoppers in Alfalfa – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CYHALOTHRIN-LAMBDA	374,959	449,259	280,317	368178	39.1%
CYFLUTHRIN	352,557	198,627	123,516	224900	23.9%
CHLORPYRIFOS	122,965	153,701	29,092	101919	10.8%
ZETA-CYPERMETHRIN	79,800	137,116	65,839	94252	10.0%
PERMETHRIN	35,250	113,315	102,359	83641	8.9%
U.S. Total	**1,046,761**	**1,136,311**	**645,173**	**942748**	**Column Total 92.6%**

Source: Proprietary third party data. Excluding seed treatment.

4.4 Benefits of Chlorpyrifos in Alfalfa

- Chlorpyrifos is the insecticide most used for control of insect pests in the West and Plains regions where approximately 68% of U.S. alfalfa acres are grown.
- Chlorpyrifos is the insecticide most used to control of aphids and armyworm nationwide.
- Effective control of the primary insect pests in alfalfa including alfalfa weevil, aphids, armyworm and leafhoppers as well as many other economically important insect pests.
- Protects crop yield.
- Provides broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests. Some alternative insecticides (chlorantraniliprole, flubendiamide) do not provide broad spectrum control, and as a result additional insecticide applications may be required to control multiple insect pests.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance. Pyrethroids (Group 3A MOA) are used extensively because they are inexpensive and broad spectrum. The availability of

chlorpyrifos allows growers to rotate between different insecticide modes of action, which helps delay resistance development in all insecticides. Resistance development to pyrethroids would proceed at an accelerated rate in the absence of chlorpyrifos.
- Cost effective.

4.5 Chlorpyrifos Formulations, Rates, and Applications

Several formulations of chlorpyrifos are listed for treating alfalfa including Lorsban 4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advances, Lorsban 75WG, Lorsban 15G (and other chlorpyrifos granular formulations), Lock-On, Cobalt and Cobalt Advanced.

Location: Midwest and Atlantic
- Pests: alfalfa weevil
- Application Type: foliar
- Application Method: ground
- Rate: 0.5-1.0 lb a.i./A
- Number of Applications: 1, only highly managed alfalfa (dairy) is treated
- Timing of Application: application made to first cutting

Location: Midwest and Atlantic
- Pests: potato leafhopper
- Application Type: foliar
- Application Method: ground
- Rate: 0.25-0.5 lb a.i./A
- Number of Applications: 1, only highly managed alfalfa (dairy) is treated
- Timing of Application: application made to second or third cutting

Location: Southern Plains (KS, OK, TX)
- Pests: alfalfa weevil
- Application Type: foliar
- Application Method: ground or air
- Rate: 0.5-1.0 lb a.i./A
- Number of Applications: 1-3
- Season of Application: application made to first cutting

Location: Southern Plains (KS, OK, TX)
- Pests: aphids
- Application Type: foliar
- Application Method: ground or air
- Rate: 0.5 – 1.0 lb a.i./A
- Number of Applications: 1
- Timing of Application: application made to first cutting

Location: CA and AZ

- Pests: alfalfa weevil, Egyptian alfalfa weevil, aphids, alfalfa caterpillar, armyworm
- Application Type: foliar
- Application Method: mainly by air
- Rate: 0.5 – 1.0 lb a.i./A (aphid control at lower rates)
- Number of Applications: 1 treatment in Central Valley; Desert alfalfa (Arizona and Imperial Valley) may receive multiple cutting treatments in years when armyworm pressure is severe
- Timing of Application: application made to first cutting

Table 15. Chemical Treatments for Insect Control in Alfalfa

Note: Information in the "Benefits, Application, Use and Efficacy" section reflect opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, Lorsban 15G, Lock-On, others	-Controls alfalfa weevil, aphids, armyworm and leafhoppers. -Broad spectrum. -Important tank mix partner for Lygus control in alfalfa grown for seed. -Group 1B MOA for resistance management. -Cost effective.
Chlorpyrifos + Gamma-Cyhalothrin/ Chlorpyrifos + Lambda-Cyhalothrin	Cobalt/ Cobalt Advanced	-Controls alfalfa weevil, aphids, armyworm and leafhoppers. -Broad spectrum. -Good knock down and residual control. -Groups 1B and 3A MOA for resistance management. -Cost effective.
Chlorantraniliprole	Prevathon	-Controls armyworm and grasshopper. -Does not control alfalfa weevil, aphids or leafhoppers. -Relatively expensive. -Group 28 MOA.
Cyfluthrin	Baythroid, others	-Controls alfalfa weevil, armyworm and leafhoppers. -Suppresses aphids. -Group 3A MOA.
Dimethoate	Several	-Controls aphids and leafhoppers. -Suppresses alfalfa weevil and no armyworm control. -Group 1B MOA.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Gamma-Cyhalothrin	Proaxis, others	-Controls alfalfa weevil, aphids, armyworm and leafhoppers. -Broad spectrum. -Group 3A MOA.
Flubendiamide	Belt	-Controls armyworm. -Does not control alfalfa weevil, aphids or leafhoppers. -Relatively expensive. -Group 28 MOA.
Indoxacarb	Steward	-Controls alfalfa weevil, armyworm and leafhopper. -Does not control aphids. -Group 1B MOA.
Lambda-Cyhalothrin	Warrior, Karate, others	-Controls alfalfa weevil, aphids, armyworm and leafhoppers. -Broad spectrum. Best performing pyrethroid. -Group 3A MOA. -Cost effective.
Malathion	Several	-Controls aphid and leafhopper control. -Less effective control of alfalfa weevil and armyworm. -Group 1B MOA.
Zeta-Cypermethrin	Mustang, others	-Controls alfalfa weevil, aphids, armyworm and leafhoppers. -Aphid control may be variable. -Broad spectrum. -Group 3A MOA.

4.6 <u>Non-Chemical Alternatives</u>

Early cutting of alfalfa will sometimes prevent serious damage by weevils, although maximum yield is not obtained when the crop is cut early for insect control [5]. Also, most weevils are killed by the harvest and curing process.

Resistant varieties of alfalfa and encouraging populations of natural enemies are very important in managing aphid in alfalfa [6] [7]. Border-strip cutting during harvest is used to help maintain populations of parasites and predators within the field. Lady beetles, green lacewings and many other predators including bigeyed bugs (*Geocoris* spp.), damsel bugs (*Nabis* spp.), and syrphid flies can also be important in regulating aphids. An introduced parasite, *Trioxys complanatus,* has become established on the spotted alfalfa aphid.

4.7 Grower Perspective

In late 2007, the EPA asked for public comments on issues related to the agricultural use of chlorpyrifos. The following is a selection of excerpts from grower organizations which responded to the EPA's request for input by explaining why they considered chlorpyrifos essential for protecting their crops. Submissions to the docket are public information, and have been posted by the EPA at www.regulations.gov, docket number EPA-HQ-OPP-2007-1005. Growers also commented during public comment periods in 2011 (EPA-HQ-OPP-2008-0850-0025) and 2015 (EPA-HQ-OPP-0850-0224).

"Alfalfa and alfalfa seed producers in many parts of the country rely heavily on the pest control benefits Lorsban [i.e., chlorpyrifos] provides. The pests it controls – alfalfa weevil, army cutworm, grasshoppers, leafhoppers, Lygus bugs, aphids – can devastate a crop.... Alfalfa seed producers are strongly advised to rotate insecticide families (i.e., organophosphates, carbamates and synthetic pyrethroids) in their Lygus control program to help prevent the development of insecticide resistance. Removing [chlorpyrifos] as one of these options increases the likelihood of the development of insect resistance." – National Alfalfa and Forage Alliance

4.8 References

1. USDA NRCS Plant Materials Program. *Alfalfa*. Plant Fact Sheet. May 26, 2006. http://plants.usda.gov/factsheet/pdf/fs_mesa.pdf. Accessed December 7, 2015.
2. Gianessi L. *The Benefits of Insecticide Use: Alfalfa*. CropLife Foundation. March 2009. https://croplifefoundation.files.wordpress.com/2012/07/combined_document_alfalfa.pdf. Accessed December 7, 2015.
3. University of Illinois, Extension and Outreach. *Alfalfa Weevil*. http://www.ipm.uiuc.edu/fieldcrops/insects/alfalfa_weevil/index.html. Accessed December 8, 2015.
4. University of California, UC IPM Online. *How to Manage Pests, Alfalfa*. http://www.ipm.ucdavis.edu/PMG/selectnewpest.alfalfa-hay.html. Accessed December 8, 2015.
5. University of California, UC IPM Online. *How to Manage Pests, Alfalfa: Weevils (Alfalfa and Alfalfa Egyptian)*. August 2015. http://www.ipm.ucdavis.edu/PMG/selectnewpest.alfalfa-hay.html. Accessed December 8, 2015.
6. University of California, UC IPM Online. *How to Manage Pests, Alfalfa: Blue Alfalfa and Pea Aphid*. August 2015. http://www.ipm.ucdavis.edu/PMG/selectnewpest.alfalfa - hay.html. Accessed December 8, 2015.
7. University of California, UC IPM Online. *How to Manage Pests, Alfalfa: Spotted Alfalfa and Pea Aphid*. August 2015. http://www.ipm.ucdavis.edu/PMG/selectnewpest.alfalfa-hay.html. Accessed December 8, 2015.

5. Asparagus

5.1 Overview

An average of 27,133 acres of asparagus was grown annually in the U.S. in 2012-2014. Over 80% of the asparagus was grown in California and Michigan.

Table 16. U.S. Asparagus Production – Acres Grown 2012-2014.

State	Acres Grown			
	2012	2013	2014	2012-2014 Average
CALIFORNIA	12,000	12,000	11,500	11,833
MICHIGAN	10,300	10,300	10,300	10,300
WASHINGTON	5,500	5,500	4,000	5,000
U.S. Total	**27,800**	**27,800**	**25,800**	**27,133**

Source: Proprietary third party data.

5.2 Chlorpyrifos Use

Chlorpyrifos was one of the three most-used insecticide active ingredients to control insect pests in asparagus, and was used on 23.0% of the total treated acres in 2012-2014.

Table 17. Leading Insecticide Active Ingredients Used in Asparagus – Acres Treated 2012–2014.

Insecticide	Acres Treated				% of Total a.i. Acres Treated (2012-2014)
	2012	2013	2014	2012-2014 Average	
CARBARYL	35,275	42,033	29,365	35,557	36.5%
PERMETHRIN	19,515	25,886	24,061	23,154	23.8%
CHLORPYRIFOS	24,748	21,375	21,023	22,382	23.0%
PYRETHRINS	1,599	5,695	1,214	2,836	2.9%
U.S. Total	**89,816**	**111,722**	**90,388**	**97,309**	**Column Total 86.3%**

Source: Proprietary third party data.

Growers used an average of 19,915 lb a.i. of chlorpyrifos annually to control insect pests in asparagus in 2012-2014, nearly equal to the average annual use in 2003-2007 (22,104 lb a.i.). Chlorpyrifos was primarily used to control asparagus beetle, cutworm and European asparagus aphid and other aphid species in asparagus. Maintaining the availability of chlorpyrifos in the asparagus insecticide complex is important for control of these insect pests and viability of long-term resistance management programs.

Table 18. Chlorpyrifos Use in Asparagus – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	24,748	21,375	21,023	22,382
Lbs a.i. Applied	20,210	19,612	19,924	19,915

Source: Proprietary third party data.

5.3 Target Pests

Asparagus beetle, aphids, plant bug and cutworm were the top target pests in asparagus and accounted for 102% of the total active ingredient acres. Each causes significant losses in asparagus as described below. Chlorpyrifos provides broad spectrum control of a number of insect pests in asparagus, and was among the leading active ingredients used to control these economically important insect pests.

Table 19. Top Insect Pests in Asparagus – Acres Treated 2012-2014.

Insect	Pest Acres				% of Total a.i. Acres Treated (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
BEETLE, ASPARAGUS	44,030	71,215	41,259	52,168	53.6%
APHID, ASPARAGUS	17,662	10,656	17,545	15,288	15.7%
APHID	9,195	19,257	12,448	13,633	14.0%
BUG, PLANT	12,095	6,548	11,144	9,929	10.2%
CUTWORM	7,480	7,511	10,344	8,445	8.7%
U.S. Total	**106,276**	**139,870**	**115,633**	**120,593**	**Column Total 102.2%**

Source: Proprietary third party data.

5.3.1 European Asparagus Aphid

Damage from European asparagus aphid is primarily from a toxin that the aphids inject into the plant when feeding. The toxin causes shortened internodes on subsequent growth, resulting in a tufted appearance that is called "bonsai growth." While other factors can cause a limited amount of this type of distorted growth, heavy European asparagus aphid infestations produce this distortion in great profusion. Heavy populations also produce massive amounts of honeydew that may lead to considerable ant activity. Because asparagus is a perennial plant, the important damage is the impact of the European asparagus aphid feeding on the subsequent year's growth. The distorted growth is unable to adequately nourish the plant's crown and it will desiccate after 1 or 2 years feeding by this pest. The toxin may also cause a delay in bud break in spring followed by a profusion of small spears produced simultaneously. The impact is especially pronounced on newly established or weak plantings, and in seedling beds [1].

Chlorpyrifos was, by far, the most-used insecticide active ingredient to control the European asparagus aphid and other aphid species in asparagus. Chlorpyrifos was used on 48.6% of the pest acres treated for aphids in 2012-2014.

Table 20. Leading Insecticide Active Ingredients Used to Control the European Asparagus Aphid and Other Aphid Species in Asparagus – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CHLORPYRIFOS	16,159	10,902	15,121	14,061	48.6%
PYRETHRINS	1,599	5,695	1,214	2,836	9.8%
AZADIRACHTIN	1,599	6,484	--	2,694	9.3%
CYHALOTHRIN-LAMBDA	1,576	3,377	1,522	2,159	7.5%
DISULFOTON	732	2,784	920	1,479	5.1%
U.S. Total	**26,856**	**29,913**	**29,994**	**28,921**	**Column Total 80.3%**

Source: Proprietary third party data.

5.3.2 Cutworm

Cutworm larvae feed at night on the tender tips of new asparagus spears where they eat small holes. One-sided feeding may also cause the spears to curl. The variegated cutworm also feeds underground and at the soil surface. Fern damage is rare [2].

Chlorpyrifos was by far the most-used insecticide active ingredient to control cutworm in asparagus. Chlorpyrifos was used on 75.8% of the pest acres treated for cutworm in 2012-2014.

Table 21. Leading Insecticide Active Ingredients Used to Control Cutworm in Asparagus – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CHLORPYRIFOS	5,956	7,346	5,908	6,403	75.8%
PERMETHRIN	1,177	--	2,457	1,211	14.3%
METHOMYL	--	--	1,305	435	5.2%
CARBARYL	348	165	674	396	4.7%
U.S. Total	**7,480**	**7,511**	**10,344**	**8,445**	**100.0%**

Source: Proprietary third party data.

5.3.3 Asparagus Beetle

Asparagus beetles injure the plant by feeding on the tips of tender young shoots. After leaves come out, asparagus beetles and their larvae gnaw on the surface of the stems and devour the leaves. If injury to the fern is severe the crown is weakened, particularly if the asparagus stand is young [3].

Chlorpyrifos was used 5.2% of the pest acres treated for asparagus beetle in 2012-2014.

Table 22. Leading Insecticide Active Ingredients Used to Control Asparagus Beetle in Asparagus – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CARBARYL	33,445	41,665	28,468	34,526	66.2%
PERMETHRIN	5,038	7,279	7,138	6,485	12.4%
CHLORPYRIFOS	3,996	3,374	811	2,727	5.2%
AZADIRACHTIN	--	6,484	--	2,162	4.1%
CYHALOTHRIN-LAMBDA	820	3,377	1,522	1,906	3.7%
U.S. Total	**44,030**	**71,215**	**41,259**	**52,168**	**Column Total 91.6%**

Source: Proprietary third party data.

5.4 Benefits of Chlorpyrifos in Asparagus

- Chlorpyrifos is the insecticide most used for control of European asparagus aphid and other aphid species, and cutworm.
- Effective control of several primary insect pests in asparagus including European asparagus aphid and other aphid species, asparagus beetle, and cutworm as well as other economically important insect pests.
- Provides broad spectrum insect control in a single application which helps reduce the number of insecticide applications necessary to control multiple pests.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.
- 1-day PHI.
- Cost effective.

5.5 Chlorpyrifos Formulations, Rates, and Applications

The formulations listed for controlling insect pests in asparagus include Lorsban-4E (and other 4 lbs per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, and Lorsban 15G (and other chlorpyrifos granular formulations).

Location: for use only in AZ, CA, ID, IL, IN, ID, KS, MI, MN, MO, NE, ND, OH, OR, SD, WA, WI.

- Pests: European asparagus aphid, aphid, asparagus beetle, cutworm, armyworms, grasshoppers, symphylans
- Application Type: foliar spray
- Application Method: ground broadcast
- Rate: 1.0 lb a.i./A
- Number of Applications: do not make more than 1 preharvest and 2 postharvest applications during the fern stage
- Season of Application: preharvest or postharvest when insects reach economic thresholds

Table 23. Leading Chemical Treatments for Insect Control in Asparagus.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, Lorsban 15G, others	-Controls European asparagus aphid, aphids, asparagus beetle, cutworm, armyworms and symphylans. -Quick knockdown of aphids. -Broad spectrum. -Group 1B MOA for resistance management. -Cost effective.
Azadirachtin	Neem Oil, several	-Insect feeding inhibitor. -Approved for certified organic crop use.

Active Ingredient	Brand Names	Application, Use, and Efficacy
		-Group UN MOA.
Carbaryl	Sevin	-Controls asparagus beetle and cutworm. -Group 1A MOA.
Methomyl	Lannate	-Controls asparagus beetle and cutworm. -Group 1A MOA.
Permethrin	Ambush, Pounce, others	-Controls asparagus beetle and cutworm. -Group 3A MOA.
Pymetrozine	Fulfill	-Controls aphids. -Group 9B MOA.

Source: [1] [2] [3].

5.6 Non-Chemical Alternatives

Mowing, chopping up, and then incorporating asparagus ferns during the dormant season or burning, where permitted, may substantially reduce asparagus aphid egg laying and insect population levels [1].

Field trash and previous crop residues should be thoroughly incorporated and weeds controlled in and around the field to reduce cutworm egg and worm overwintering [2].

5.7 References

1. University of California, UC IPM Online. *How to Manage Pests, Asparagus/European Asparagus Aphid*. February 2012. http://www.ipm.ucdavis.edu/PMG/r730011l.html. Accessed December 27, 2015.
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6. Brassica Vegetables (cole crops)

6.1 Overview

Brassica vegetables include broccoli, Brussels sprouts, cabbage, cauliflower, radishes, rutabaga, turnips, greens and other smaller acreage crops. Broccoli, cabbage and cauliflower are the major brassica vegetables and are detailed in this section. Little information is available for chlorpyrifos use on the other brassica crops.

An average of 219,267 acres of brassica vegetables was planted annually in the U.S. in 2012-2014. Broccoli was the leading brassica vegetable crop grown in the U.S. with 55% of all brassica vegetable planted acres, followed by cabbage with 28% and cauliflower with 17%. Seventy seven percent of brassica vegetables acres were grown in California, including 100% of the broccoli, 90.2% of the cauliflower and 21.5% of the cabbage acres. California grew an average of 121,667 acres of broccoli, 13,133 acres of cabbage and 33,000 acres of cauliflower in 2012-2014. Nearly 75% of the cabbage acres were grown commercially in five states; California, New York, Florida, Texas and Georgia.

Table 24. U.S. Brassica Vegetable Production – Acres Planted 2012-2014.

Crop	State	Acres Planted			
		2012	2013	2014	2012-2014 Average
Broccoli	CALIFORNIA	121,000	121,000	123,000	121,667
	Total	**121,000**	**121,000**	**123,000**	**121,667**
Cabbage	CALIFORNIA	11,500	11,500	16,400	13,133
	NEW YORK	10,900	10,900	8,600	10,133
	FLORIDA	9,900	9,900	9,500	9,767
	TEXAS	7,000	7,000	6,500	6,833
	GEORGIA	5,600	5,600	5,500	5,567
	NORTH CAROLINA	4,800	4,800	2,900	4,167
	ARIZONA	2,900	2,900	3,700	3,167
	MICHIGAN	3,000	3,000	3,200	3,067
	WISCONSIN	3,100	3,100	3,000	3,067
	COLORADO	2,500	2,500	1,300	2,100
	Total	**61,200**	**61,200**	**60,600**	**61,000**
Cauliflower	CALIFORNIA	32,400	32,400	34,200	33,000
	ARIZONA	3,600	3,600	3,600	3,600
	Total	**36,000**	**36,000**	**37,800**	**36,600**
U.S. Total		**218,200**	**218,200**	**221,400**	**219,267**

Source: Proprietary third party data.

Nearly all of the 2,200 acres of Brussels sprouts grown in 2006, the last year data was available from NASS, were produced in California. Approximately 60% of the 15,800 acres of radishes grown in 2001 were produced in Florida, and the rest were produced in

California, Michigan and Ohio. A majority of the 40,940 commercially grown acres of greens were produced in the Southern states in 2001.

6.2 Chlorpyrifos Use

Although chlorpyrifos use in brassica crops averaged only 3.0% of all active ingredient acres treated on these crops in 2012-2014, it is an important tool in U.S. brassica crop production systems. Growers used an average of 68,627 lb a.i. of chlorpyrifos annually to control insect pests in brassica crops in 2012-2014, a 49% decrease in average annual use from 2003-2007 (134,136 lb a.i.). Chlorpyrifos was the most-used active ingredient for controlling cabbage maggot in brassica crops. Maintaining the availability of chlorpyrifos in the brassica crop insecticide complex is important for control of this insect pest and the viability of long-term resistance management programs.

Table 25. Chlorpyrifos Use in Brassica Vegetables – Acres Treated and Lb. a.i. Applied 2012-2014.

Crop	Data	2012	2013	2014	2012-2014 Average
Broccoli	Acres Treated	50,281	20,160	25,627	32,023
	Lbs a.i. Applied	85,939	39,429	46,171	57,180
Cabbage	Acres Treated	12,207	912	3,412	5,510
	Lbs a.i. Applied	13,676	1,365	3,421	6,154
Cauliflower	Acres Treated	9,393	5,361	--	4,918
	Lbs a.i. Applied	10,250	5,629	--	5,293
Total US	**Acres Treated**	**71,881**	**26,433**	**29,039**	**42,451**
	Lbs a.i. Applied	**109,865**	**46,423**	**49,592**	**68,627**

Source: Proprietary third party data.

Some variation in acres treated and lbs a.i. applied were found comparing CDPR and proprietary third party data for chlorpyrifos use in broccoli and cauliflower.

Table 26. Chlorpyrifos Use in California Broccoli – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	Data Source	2012	2013	2014	2012-2014 Average
Acres Treated	CDPR	12,109	5,015	3,729	6,951
	Proprietary third party	50,281	20,160	25,627	32,023
Lb a.i. Applied	CDPR	16,168	6,462	4,104	8,911
	Proprietary third party	85,939	39,429	46,171	57180

Table 27. Chlorpyrifos Use in California Cauliflower – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	Data Source	2012	2013	2014	2012-2014 Average
Acres Treated	CDPR	3,328	709	184	1,407
	Proprietary third party	9,393	5,361	--	4,918
Lb a.i. Applied	CDPR	3,676	795	201	1,557
	Proprietary third party	10,250	5,629	--	5,293

The California Department of Pesticide Regulation estimated that 4,000 lb a.i. of chlorpyrifos was used on Brussels sprouts annually from 2004-2013 [1]. No information was provided for the average or maximum treated acreage. No information was available for chlorpyrifos use on radishes, rutabaga, turnips, greens or other brassica vegetable crops.

6.3 Target Pests

While aphids, diamondback moth, cabbage looper and armyworm are the top target pests in brassica crops; other insect pests like the cabbage maggot can damage thousands of acres of broccoli, cabbage and cauliflower. Chlorpyrifos was, by far, the leading active ingredient used to control cabbage maggot in brassica vegetables and accounted for over 37.1% of the pest active ingredient acres treated for maggots in 2012-2014.

Table 28. Leading Insecticide Active Ingredients Used to Control Maggots (Cabbage, Root, Seed) in Brassica Vegetables – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CHLORPYRIFOS	54,806	24,256	28,954	36,005	37.1%
IMIDACLOPRID	84	13,331	30,137	14,517	14.9%
CYFLUTHRIN	--	10,859	30,137	13,665	14.1%
BIFENTHRIN	170	5,670	28,941	11,594	11.9%
CLOTHIANIDIN	--	4,167	16,408	6,858	7.1%
U.S. Total	**58,440**	**82,616**	**150,430**	**97,162**	**Column Total 85.1%**

Source: Proprietary third party data.

6.3.1 Cabbage Maggot (root maggot)

Cabbage maggots damage and destroy root systems of all brassica crops, riddling roots with tunnels when infestations are heavy. Tunnels provide entryways for pathogens that cause blackleg and bacterial soft rot. Young plants from seedling emergence to approximately a month after thinning or transplanting are most vulnerable [2] [3] [4].

Direct application of insecticides to the root zone is considered the most effective treatment to control cabbage maggot. Insecticides are applied as a narrow band with enough water to penetrate the root zone. Some materials may be applied as a transplant tray drench or in transplant water, or in-furrow before or during seeding or transplanting.

Two organophosphate (Group 1B) insecticides, chlorpyrifos and diazinon, and bifenthrin, a Group 3A insecticide, are registered for use on brassica crops to control root maggot [5]. Chlorpyrifos is strongly preferred by growers over diazinon and bifenthrin. Bifenthrin was used on 11.9% of the pest acres treated for root maggot versus 37.1% for chlorpyrifos. Diazinon was used in cabbage for root maggot control, but on significantly fewer acres than chlorpyrifos (4,268 chlorpyrifos pest acres versus diazinon 1,538 pest acres), and was not used at all in broccoli or cauliflower to control root maggot in 2012-2014.

There are limited choices in chemicals approved for use to control cabbage maggot, and the limited modes of action registered represents a challenge for insect resistance management. Chlorpyrifos is the insecticide most used for cabbage maggot control, and the availability of a Group 1B insecticide for mode of action rotation is critical for resistance management.

6.4 Benefits of Chlorpyrifos in Brassica Vegetables

- Chlorpyrifos is the insecticide most used for cabbage maggot control in brassica vegetables. Chlorpyrifos is highly preferred over diazinon, the only other approved group 1B insecticide, and bifenthrin for cabbage maggot control.
- Effective rotational partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance development.
- Cost effective.

6.5 Chlorpyrifos Formulations, Rates, and Applications

The formulations registered for controlling insect pests in brassica vegetables include Lorsban 15G (and other chlorpyrifos granular formulations), Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, and Lorsban 75WG.

Location: CA

- Crops: broccoli, Brussels sprouts, cabbage, cauliflower
- Pests: cabbage root maggot, root aphid
- Application Type: spray

- Application Method: at-plant or post-plant band, or broadcast preplant incorporated
- Rate: band 1.6-2.75 fl. oz. of Lorsban-4E/1000 ft of row, or band 4.6-9.2 oz (0.7-1.4 oz a.i.) of Lorsban 15G/1000 ft of row, or broadcast and incorporate 2-2.25 lb a.i./A Lorsban-4E
- Number of Applications: 1

Location: CA, FL, MI, OH

- Crops: radishes
- Pests: cabbage root maggot
- Application Type: ground
- Application Method: at-plant or post-plant band, or broadcast preplant incorporated
- Rate: band 1.0 fl. oz. of Lorsban-4E/1000 ft of row, or band 3.3 oz of Lorsban 15G/1000 ft of row, or broadcast and incorporate 2.25 lb a.i./A of Lorsban-4E
- Number of Applications: 1

Location: AL, CA, GA, NC, SC. TX

- Crops: collards, kale, rutabaga, turnip
- Pests: cabbage root maggot
- Application Type: ground
- Application Method: at-plant or post-plant band, or broadcast preplant incorporated
- Rate: band 1.6-2.75 fl. oz. of Lorsban-4E/1000 ft of row, or band 4.6-9.2 oz of Lorsban 15G/1000 ft of row, or broadcast and incorporate 2.25 lb a.i./A of Lorsban-4E
- Number of Applications: 1

Table 29. Leading Chemical Treatments for Insect Control in Brassica Vegetables.

Note: Information in the "Application, Use and Efficacy" section reflects opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, Lorsban 15G, others	-At-plant or post-plant band application controls cabbage maggot and cabbage aphid. -Broadcast preplant incorporated application controls root maggot, billbugs, wireworms, grubs, symphylans and wireworms. -Broad spectrum. -Group 1B MOA for resistance management. -Cost effective.
Bifenthrin	Capture	-At-plant or post-plant band application controls cabbage maggot, corn rootworm,

Active Ingredient	Brand Names	Application, Use, and Efficacy
		wireworm, grubs and provides early season control of lettuce root aphid, cutworm and armyworm. -Broad spectrum. -Group 3A MOA.
Diazinon	Several	-Transplant water drench application controls cabbage maggots. -Broadcast preplant incorporated application controls cabbage maggots, wireworms, mole crickets and provides early season control of cutworms. -Broad spectrum. Group 1B MOA.

6.6 Non-Chemical Alternatives

Once cabbage maggot damage is noticed, it is too late to apply control procedures. Economic thresholds are not used for cabbage maggot and all management options are preventive. Since the first generation of cabbage maggots is the most damaging, planting seeds or transplants after the peak of adult emergence and egg laying in the spring may reduce cabbage maggot infestation levels.

6.7 Grower Perspective

In late 2007, the EPA asked for public comments on issues related to the agricultural use of chlorpyrifos. Following are excerpts from grower organizations explaining why chlorpyrifos is essential for protecting crops. Submissions to the docket are public information and have been posted by the EPA at www.regulations.gov, docket number EPA-HQ-OPP-2007-1005. Growers also commented during public comment periods in 2011 (EPA-HQ-OPP-2008-0850-0025) and 2015 (EPA-HQ-OPP-0850-0224).

"... Oregon growers use it [chlorpyrifos] quite regularly to control insects such as cabbage maggot on broccoli and cauliflower...Growers have not found alternative products that offer the control of chlorpyrifos. Elimination of chlorpyrifos would have significant negative impacts on Oregon growers' ability to competitively produce processed vegetable crops and consequently would severely hamper the entire processed vegetable industry in the state." – Oregon Processed Vegetable Commission

"The directors of the Maine Vegetable and Small Fruit Growers Association support the continued use of the active ingredient chlorpyrifos for agricultural production. In Maine, the principle agricultural uses of chlorpyrifos are in field corn, sweet corn, broccoli, cabbage and other cole crops, and strawberries. For broccoli and other cole crops, it is the only active ingredient available that effectively controls...root maggot. For our other

crops, this is an important active ingredient to maintain in order to be able to provide a rotation to effectively manage insect resistance development." – Maine Vegetable and Small Fruit Growers Association

6.8 Crop Consultant Perspective

In preparing this report, growers and crop consultants were recently asked to share their thoughts on the benefits and use of chlorpyrifos for pest control.

"For cole crops, chlorpyrifos provides good protection against seed corn maggot at planting. It's a valuable pest control tool. We keep losing products that were previously available to us for pest control, and now there are very few soil-applied options available. As a result, we are seeing pests like garden symphylans appear, which didn't happen back when we had more options to rotate in." – Kevin Vaughan, Crop Production Services, Greenfield, CA, (April 2009)

6.9 References

1. U.S. Environmental Protection Agency. *Chlorpyrifos (059101), Screening Level Usage Analysis (SLUA). Date: March 13, 2015. APPENDIX 1-8: Usage Data for Chlorpyrifos.* March, 13, 2015. https://www.google.com/webhp?sourceid=chrome-instant&ion=1&espv=2&ie=UTF-8#q=appendix+1-8%3A+Usage+data+for+chlorpyrifos. Accessed December 30, 2015.
2. University of California, UC IPM Online. *How to Manage Pests, Cole Crops/Cabbage Maggot*. September 2009. http://www.ipm.ucdavis.edu/PMG/r108300811.html. Accessed December 23, 2015
3. Griffin, R.P., Williamson, J. Clemson University. *Cabbage, Broccoli & Other Cole Crop Insect Pests*. July 2015. http://www.clemson.edu/extension/hgic/pests/plant_pests/veg_fruit/hgic2203.html Accessed December 23. December, 23, 2015
4. Van Wychen Bennett, K., E. C. Burkness and W. D. Hutchison. University of Minnesota. *Cabbage Maggot*. http://www.vegedge.umn.edu/pest-profiles/pests/cabbage-maggot. Accessed December 23, 2015.
5. University of Illinois, Extension. Purdue Extension, K-State Research and Extension, University of Minnesota Extension, University of Missouri Extension. *Midwest Vegetable Production Guide for Commercial Growers 2016*. December 2015. https://ag.purdue.edu/btny/midwest-vegetable-guide/Pages/default.aspx. Accessed December 31, 2015.

7. Carrots (grown for seed)

7.1 Chlorpyrifos Use

A 24(c) Special Local Need label allows the use of chlorpyrifos (Lorsban Advanced) to control cutworm and Lygus bug on carrots grown for seed in Oregon and Washington state (24c SLNs: OR-090011 [expires 12/31/18], WA-090011 [expires 12/31/16]). No information was available on the number of treated acres or lb a.i. of chlorpyrifos applied for this use.

7.2 Target Pests

Aphid, cutworm, Lygus bug and two-spotted spider mite are primary insect pests of carrots grown for seed in the Pacific Northwest [1]. Cutworms and Lygus bug are especially destructive and difficult to control. Cutworms cut off young plants at ground level or feed on foliage at night [2]. Lygus bugs use piercing-sucking mouthparts to feed on the umbels, which causes aborted buds, blossom drop and shriveled seeds. Adults and late stage nymphs are the most injurious stages, but smaller nymphs are easiest to control [3].

7.3 Benefits of Chlorpyrifos in Carrots

- Effective control of cutworms and Lygus bug, as well as, other economically important insect pests.
- Broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.
- Cost effective.

7.4 Chlorpyrifos Formulations, Rates, and Applications

The formulation listed for control of cutworm and Lygus bug in carrots grown for seed in Oregon and Washington is Lorsban Advanced.

Location: OR, WA

- Product: Lorsban Advanced
- Pests: cutworm and Lygus bug
- Application Type: foliar
- Application Method: ground
- Rate: 0.94 lb a.i./A
- Number of Applications: 1
- Season of Application: apply after carrots have started to bolt and when field counts or crop injury indicate that damaging pest populations are developing or present
- Other: no portion of treated plants can be used for food or feed

7.5 References

1. Pacific Northwest Insect Management Handbook. *Vegetable Seed Crops/Pests of Carrot Grown for Seed*. March 2015. http://insect.pnwhandbooks.org/vegetable-seed/carrot. Accessed December 30, 2015.
2. Pacific Northwest Insect Management Handbook. *Vegetable Seed Crops/Pests of Carrot Grown for Seed/Carrot Seed-Cutworm*. March 2015. http://insect.pnwhandbooks.org/vegetable-seed/carrot/carrot-seed-lygus-bug#sthash.mwVHyL9w.dpuf. Accessed December 30, 2015.
3. Pacific Northwest Insect Management Handbook. *Vegetable Seed Crops/Pests of Carrot Grown for Seed/Carrot Seed-Lygus Bug*. March 2015. http://insect.pnwhandbooks.org/vegetable-seed/carrot/carrot-seed-lygus-bug#sthash.mwVHyL9w.dpuf. Accessed December 30, 2015.

8. Citrus

8.1 Overview

Citrus crops are divided into six major groups: oranges, grapefruit, lemons, limes, tangelos and tangerines. An average of 771,000 acres of citrus crops were grown annually in the U.S. in 2012-2014 (USDA, NASS). Total citrus acres in the U.S. have declined 33% over the past decade from the 1,129,205 acres grown in 2004. The top citrus producing states are Florida (oranges and grapefruit), California (oranges, lemons, and grapefruit), Texas (grapefruit), and Arizona (lemons). Sixty-six percent of U.S. citrus acres are in Florida. Florida and California combined account for over 90% of total U.S. citrus acres.

8.1.1 Oranges

The U.S. is the second largest orange-producing country in the world. Florida is the leading U.S. state for orange production, followed by California. A majority of Florida's orange crop is processed, while most of California's oranges are marketed as fresh fruit for domestic and export use. The U.S. produced 6.8 million tons valued at $1.96 billion in 2014 (USDA, NASS).

Table 30. U.S. Orange Production – Acres Grown 2012-2014.

State	Acres Grown			
	2012	2013	2014	2012-2014 Average
FLORIDA	511,195	506,241	443,315	486,917
CALIFORNIA	197,786	195,551	185,173	192,837
U.S. Total	**708,981**	**701,792**	**628,488**	**679,754**

Source: Proprietary third party data.

8.1.2 Grapefruit

The U.S. is one the major producers of grapefruit around the world. Only three states, Florida, California and Texas, produce grapefruit commercially in the U.S. California's acreage dropped below 10,000 acres in 2014, and was not included in the acres grown data. The U.S. produced 1.0 million tons valued at $232 million in 2014 (USDA, NASS).

Table 31. U.S. Grapefruit Production – Acres Grown 2012-2014.

State	Acres Grown			
	2012	2013	2014	2012-2014 Average
FLORIDA	57,558	56,799	45,875	53,411
TEXAS	18,650	18,650	17,759	18,353
U.S. Total	**76,208**	**75,449**	**63,634**	**71,764**

Source: Proprietary third party data.

8.1.3 Lemons

California produces approximately 85% of the U.S. lemon crop, with Arizona producing the remainder. Approximately two thirds of the lemon crop is marketed as fresh fruit with the remainder used in processing. The U.S. produced 824,000 tons valued at $648 million in 2014 (USDA, NASS).

Table 32. U.S. Lemon Production – Acres Grown 2012-2014.

State	Area Grown			
	2012	2013	2014	2012-2014 Average
CALIFORNIA	49,905	49,905	51,742	50,517
ARIZONA	10,313	10,313	8,778	9,801
U.S. Total	**60,218**	**60,218**	**60,520**	**60,319**

Source: Proprietary third party data.

8.2 Chlorpyrifos Use

The total number of chlorpyrifos treated acres in citrus declined 50% from 438,399 acres in 2007 to an average of 221,467 treated acres annually in 2012-2014, and was nearly equal to the number of acres treated in 2004 (207,495 acres). The decrease in chlorpyrifos use in 2012-2014 resulted from the progressive decline in citrus acres, and the introduction of alternative insecticides to control Asian citrus psyllid.

Nationally, chlorpyrifos was the tenth most often applied insecticide on citrus, accounting for 3.7% of active ingredient treated acres averaged over 2012-2014. Chlorpyrifos was the sixth leading active ingredient used in California and ranked eleventh in Florida, accounting for 6.0% and 3.1%, respectively, of active ingredient treated acres in each state in 2012-2014.

Table 33. Leading Insecticide Active Ingredients Used in U.S. Citrus – Acres Treated 2012–2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
PETROLEUM OIL	899,034	881,613	820,023	866,890	14.4%
ABAMECTIN	835,868	869,970	730,581	812,139	13.5%
ZETA-CYPERMETHRIN	587,888	748,046	511,770	615,901	10.2%
IMIDACLOPRID	448,121	480,494	317,738	415,451	6.9%
SULFUR	338,912	311,112	319,297	323,107	5.4%
FENPROPATHRIN	269,179	270,489	390,963	310,211	5.1%
THIAMETHOXAM	274,296	302,890	337,265	304,817	5.1%
SPINETORAM	239,032	320,889	303,421	287,781	4.8%
SPIROTETRAMAT	178,232	287,878	243,172	236,427	3.9%
CHLORPYRIFOS	230,737	239,999	193,666	221,467	3.7%
DIMETHOATE	149,783	247,766	202,377	199,975	3.3%
SPIRODICLOFEN	164,474	149,805	189,237	167,839	2.8%
U.S. Total	**5,876,302**	**6,378,886**	**5,825,973**	**6,027,054**	**Column Total 79.0%**

Source: Proprietary third party data.

Growers used an average of 477,976 lb a.i. of chlorpyrifos annually to control insect pests in citrus in 2012-2014, a 26% decrease in average annual use from 2003-2007 (646,473 lb a.i.).

Table 34. U.S. Chlorpyrifos Use in Citrus – Active Ingredient Acres 2012-2014.

Crop	Lb. a.i. Applied			
	2012	2013	2014	2012-2014 Average
Oranges	374,335	447,781	282,221	368,112
Grapefruit	41,974	56,510	130,533	76,339
Lemons	30,770	17,699	52,107	33,525
U.S. Total	**447,079**	**521,990**	**464,861**	**477,976**

Source: Proprietary third party data.

8.3 <u>Florida Citrus</u>

Florida citrus accounted for 79% of all citrus active ingredient treated acres, and 64% of all insecticide expenditures in 2012-2014.

8.3.1 Target Pests

The top three citrus pests treated with insecticides in Florida are Asian citrus psyllid, rust mite, and citrus leaf miner. These insects account for 131.7% of active ingredient treated acres in Florida. Chlorpyrifos controls these three economically important citrus insect pests.

Table 35. Top Insect Pests in Florida Citrus – Pest Acres 2012-2014.

Insecticide	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
PSYLLID, ASIATIC CITRUS	3,085,762	3,739,435	3,132,818	3,319,338	69.8%
MITE, CITRUS RUST	2,171,263	1,980,159	1,878,942	2,010,122	42.3%
LEAFMINER	933,593	839,404	1,057,425	943,474	19.8%
MITE, SPIDER	447,677	524,204	331,328	434,403	9.1%
LEAFMINER, CITRUS	556,791	278,560	192,949	342,767	7.2%
MITE	172,464	110,129	286,661	189,751	4.0%
U.S. Total	**8,458,376**	**8,252,172**	**7,694,860**	**8135136**	**Column Total 152.3%**

Source: Proprietary third party data.

8.3.1.1 Asian Citrus Psyllid

Asian citrus psyllid is important in citrus production because it is the vector for the economically devastating citrus greening disease. Citrus greening, also called Huanglongbing or yellow dragon disease, is one of the most serious diseases of citrus. Infected trees are stunted and sparsely foliated. Twig dieback and leaf and fruit drop occur. Fruit produced by infected trees are small, lopsided, hard, and do not properly color. The juice is bitter. This bacterial disease is thought to have originated in China in the early 1900s, and is primarily spread by two species of psyllid insects. One species, the Asian citrus psyllid, *Diaphorina citri*, has been present in Florida since 1998 [1]. Both Asian citrus psylla and citrus greening disease are established in Florida and Texas.

8.3.1.2 Citrus Rust Mite

The citrus rust mite and the pink citrus rust mite are found on all citrus varieties throughout Florida. The citrus rust mite is usually the prevalent species, however, the pink citrus rust mite develops to greater damaging populations early in the season (April-May). Both rust mites can co-exist on the same leaf or fruit, and both are important pests of fruit grown for the fresh market. Fruit damage is the main concern with other varieties. Both mites feed on green stems, leaves, and fruit with the pink citrus rust mite being potentially more destructive [3].

8.3.1.3 Citrus Leafminer

Citrus leafminer larvae feed by creating shallow tunnels, referred to as mines, in young leaves. 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 is likely to cause damage in nurseries and new plantings because the growth of young trees is retarded by leafminer infestations. In Florida, citrus leafminer creates openings that allow for entry of citrus bacterial canker into the tree resulting in infection. Citrus bacterial canker is not found in California [4].

8.3.2 Chlorpyrifos Use in Florida

Chlorpyrifos is the 11th most-used active ingredient in Florida citrus. Chlorpyrifos use in Florida citrus increased significantly in 2007 primarily to control the Asian citrus psyllid, which is the vector of the bacteria that causes citrus greening. Since then, chlorpyrifos use has declined because of the progressive decline in citrus acres, and introduction of alternative insecticides to control Asian citrus psyllid.

Table 36. Leading Insecticide Active Ingredients Used in Florida Citrus – Acres Treated 2012–2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
ABAMECTIN	732,555	748,250	601,857	694220	14.6%
PETROLEUM OIL	692,535	652,406	613,635	652859	13.7%
ZETA-CYPERMETHRIN	579,001	714,407	457,046	583485	12.3%
IMIDACLOPRID	386,802	423,010	214,430	341414	7.2%
SULFUR	319,650	277,390	277,313	291451	6.1%
FENPROPATHRIN	230,267	234,036	348,685	270996	5.7%
THIAMETHOXAM	241,001	280,971	247,220	256397	5.4%
DIMETHOATE	128,046	231,335	191,391	183590	3.9%
SPIROTETRAMAT	123,903	227,888	160,060	170617	3.6%
MALATHION	141,841	199,195	156,236	165757	3.5%
CHLORPYRIFOS	144,195	176,226	126,720	149047	3.1%
SPIRODICLOFEN	138,749	132,236	167,643	146209	3.1%
U.S. Total	**3,506,196**	**2,368,300**	**2,749,606**	**2,874,700**	**Column Total 82.1%**

Source: Proprietary third party data.

Approximately 86% of chlorpyrifos active ingredient acres were used to control Asian citrus psyllid in 2012-2014. Citrus rust mite, scale, leafminer, aphid, and mealybug were other major insect pests growers targeted with chlorpyrifos.

Table 37. Top Insect Pests in Treated with Chlorpyrifos in Florida Citrus – Pest Acres 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
PSYLLID, ASIATIC CITRUS	118,470	157,692	108,759	128,307	85.9%
MITE, CITRUS RUST	45,741	26,180	42,390	38,104	25.5%
SCALE	11,626	9,589	16,352	12,522	8.4%
LEAFMINER	20,679	--	13,718	11,466	7.7%
APHID	11,870	9,564	2,880	8,105	5.4%
MEALYBUG	4,392	10,429	6,941	7,254	4.9%
ANT	9,397	2,736	4,677	5,603	3.8%
U.S. Total	**277,197**	**244,286**	**225,138**	**248,874**	**Column Total 141.6%**

Source: Proprietary third party data.

Florida citrus crops are currently being treated up to eight times per year with insecticides to reduce Asian citrus psyllid and slow the spread of citrus greening. Pesticides can reduce the number of psylla, but an adult psyllid carries the bacteria its entire life, and can transmit the disease faster than some pesticides can kill it [5].

Nine insecticides: zeta-cypermethrin, abamectin, imidacloprid, petroleum oil, fenpropathrin, thiamethoxam, dimethoate, malathion, and chlorpyrifos accounted for 53.6% of all active ingredient acres used for Asian citrus psyllid control in Florida. Chlorpyrifos was also used to control scale insects, mealybugs, aphids, ants, orange dog, grasshoppers, katydids, rust mites and leaf miners because of its broad spectrum. Nearly all chlorpyrifos applications in citrus are applied with petroleum oil. The average cost of chlorpyrifos on citrus was $14.59 per acre, which was slightly less than the average cost of all insecticide active ingredients ($15.12 per acre) used on citrus.

8.4 California Citrus

8.4.1 Target Pests

A number of insect pests threaten California citrus including scale (red and citricola), thrips, katydids and mites. Chlorpyrifos is one of the most frequently used active ingredients for control of scale and katydids.

Table 38. Top Insect Pests in California Citrus – Pest Acres 2012-2014.

Insecticide	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
THRIP, CITRUS	251,548	206,809	305,664	254,674	23.1%
KATYDID	137,140	139,120	153,702	143,321	13.0%
SCALE, CALIFORNIA RED	169,064	109,379	86,211	121,552	11.0%
SCALE, RED	78,811	100,100	170,868	116,593	10.6%
THRIP	84,252	159,113	85,479	109,615	9.9%
MITE, CITRUS	81,024	81,794	123,509	95,443	8.6%
SCALE, CITRICOLA	122,427	75,233	51,438	83,033	7.5%
PSYLLID, ASIATIC CITRUS	34,722	40,710	95,918	57,116	5.2%
U.S. Total	**1,296,209**	**1,430,599**	**1,664,169**	**1,463,659**	Column Total **88.9%**

Source: Proprietary third party data.

8.4.1.1 California Red Scale

California red scale is one of the key pests of citrus in California. Significant economic damage results from red scale insects settling on the fruit, causing cosmetic flaws and downgrading the fruit quality. There is a very low threshold for California red scale in citrus orchards. To keep populations below the threshold, growers have traditionally relied on high-volume sprays (up to 1,000 gallons per acre) of insecticides [6].

8.4.1.2 Citricola Scale

Citricola scale is a serious pest 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 excrete honeydew which accumulates on leaves and fruit. Sooty mold grows on honeydew, interfering with photosynthesis in leaves and causing fruit to be downgraded in quality during packing [7].

8.4.1.3 Katydid

Katydid nymphs feed on young fruit at petal fall with subsequent buildup of scar tissue and distortion of expanding fruit. A few katydids can damage a large quantity of fruit in a short time because they take a single bite from a fruit and then move to another feeding site on the same or nearby fruit. They also eat holes in leaves and maturing fruit, creating injury that resembles damage by citrus cutworm. Katydids have become more numerous with the reduced use of organophosphate and carbamate insecticides [8].

8.4.2 Chlorpyrifos Use in California

Chlorpyrifos was the sixth most frequently used insecticide active ingredient for insect pest control in California citrus. Chlorpyrifos was used on an average of 65,688 active ingredient treated acres annually in 2012-2014. Petroleum oil is used as a tank mix product with chlorpyrifos in about 25% of applications.

Table 39. Leading Insecticide Active Ingredients Used in California Citrus – Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014
	2012	2013	2014	2012-2014 Average	
PETROLEUM OIL	187,634	227,091	206,389	207,038	18.8%
SPINETORAM	138,024	170,703	157,411	155,380	14.1%
ABAMECTIN	65,465	87,541	96,301	83,102	7.5%
PYRIPROXYFEN	76,138	77,386	86,793	80,106	7.3%
CYFLUTHRIN	75,392	39,580	82,520	65,831	6.0%
CHLORPYRIFOS	85,294	61,982	49,788	65,688	6.0%
IMIDACLOPRID	60,070	53,186	74,997	62,751	5.7%
SPIROTETRAMAT	49,647	52,224	66,383	56,085	5.1%
U.S. Total	**1,057,903**	**1,049,149**	**1,203,795**	**1,103,616**	**Column Total 70.3%**

Source: Proprietary third party data.

8.4.2.1 California Oranges

The top arthropod pests in oranges are thrips, scale, katydids and mites. Chlorpyrifos was the sixth most frequently applied active ingredient for controlling pests in oranges. Chlorpyrifos was used on an average of 53,693 active ingredient treated acres annually in 2012-2014.

Table 40. Leading Insecticide Active Ingredients Used in California Oranges – Acres Treated 2012–2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
PETROLEUM OIL	168,545	200,533	140,770	169,950	18.3%
SPINETORAM	114,654	147,327	141,555	134,512	14.5%
PYRIPROXYFEN	71,967	73,544	80,760	75,424	8.1%
ABAMECTIN	47,001	66,403	67,153	60,186	6.5%
CYFLUTHRIN	70,244	34,710	74,548	59,834	6.4%
CHLORPYRIFOS	75,081	54,232	32,578	53,963	5.8%
IMIDACLOPRID	45,221	37,311	59,821	47,451	5.1%
SPIROTETRAMAT	38,453	36,338	57,700	44,163	4.8%
U.S. Total	**920,638**	**887,108**	**976,653**	**928,133**	**Column Total 69.5%**

Source: Proprietary third party data.

Some variation in acres treated and lbs a.i. applied were found comparing CDPR and proprietary third party data for chlorpyrifos use in oranges.

Table 41. Chlorpyrifos Use in California Oranges – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	Data Source	2012	2013	2014	2012-2014 Average
Acres Treated	CDPR	42,020	49,533	45,487	45,680
	Proprietary third party	75,081	54,232	32,578	53,963
Lb a.i. Applied	CDPR	127,346	153,171	159,868	146795
	Proprietary third party	218,750	179,679	102,904	167,111

8.4.2.2 California Lemons

The top arthropod pests in oranges are mites, scale and thrips. Chlorpyrifos was the third most-used active ingredient for controlling pests in lemons. Chlorpyrifos was applied on an average of 11,725 active ingredient acres annually in 2012-2014.

Table 42. Leading Insecticide Active Ingredients Used in California Lemons – Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
PETROLEUM OIL	19,089	26,558	65,618	37,088	28.9%
ABAMECTIN	18,464	21,138	29,148	22,916	12.8%
CHLORPYRIFOS	10,214	7,750	17,210	11,725	7.6%
SPINETORAM	23,370	23,376	15,857	20,868	7.0%
IMIDACLOPRID	14,849	15,875	15,176	15,300	6.7%
SULFUR	13,799	16,986	13,074	14,620	5.8%
U.S. Total	**137,266**	**162,041**	**227,142**	**175,483**	Column Total **68.7%**

Source: Proprietary third party data.

Some variation in acres treated and lbs a.i. applied were found comparing CDPR and proprietary third party data for chlorpyrifos use in lemons.

Table 43. Chlorpyrifos Use in California Lemons – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	Data Source	2012	2013	2014	2012-2014 Average
Acres Treated	CDPR	6,989	9,740	10,952	9,227
	Proprietary third party	10,214	7,750	17,210	11,725
Lb a.i. Applied	CDPR	19,334	29,853	36,241	28,476
	Proprietary third party	30,770	17,699	52,107	33,525

8.5 Benefits of Chlorpyrifos in Citrus

- **Chlorpyrifos for Control of Citricola and Red Scale** – Use of chlorpyrifos is favored by growers due to high efficacy against citricola and red scale, and relatively short residual profile compared to other products. Other insecticides that are effective against red scale are not effective against citricola scale. The bulk of California citrus is targeted at the fresh market, and a large percentage of the crop is grown for export and marketed as fresh fruit. There is a low threshold for cosmetic injury, and significant dockage and loss of export opportunity occurs with detectable California red scale on the fruit.
- **Importance of Chlorpyrifos of use in Integrated Pest Management Programs in Citrus** – Chlorpyrifos has minimal impact on the beneficial *Aphytis* wasp, which is important for late season biocontrol of California red scale populations. Control of scales in California citrus, especially oranges and lemons, is a high

anxiety issue for the producers. It has been documented that some insecticide alternatives to chlorpyrifos have a negative impact on the vedalia beetle, a beneficial predatory insect used as biological control to naturally regulate populations of cottony cushion scale in citrus. "The vedalia beetle is very sensitive to Baythroid [cyfluthrin], an insecticide being used for citrus thrips control. Baythroid kills the beetles and prevents them from laying eggs for about one month." "The vedalia beetle is also very sensitive to the insect growth regulators, Esteem (=Knack, pyriproxifen) and Applaud (buprofezin) which are applied for California red scale control. The insect growth regulators prevent vedalia from pupating and emerging as adults, and in the case of Esteem they prevent the adults from laying fertile eggs" [9].

- **Cost Effective Control Measure for All Major Citrus Pests –** Citrus is sprayed multiple times during the year regardless of the region it is grown. Either more expensive alternatives or more pyrethroids would be used should chlorpyrifos no longer be available.
- **Asian Citrus Psyllid –** Both Asian citrus psylla and citrus greening disease are established in Florida and Texas. Although Asian citrus psylla is established in Southern California and the southern portion of the Central Valley of California, the citrus greening disease has not yet become broadly established in the state. Citrus greening was found in March, 2012 in a tree in a yard in Los Angeles County, and is present in Mexico. There is major concern in California that the disease will spread through the movement of infected plants or infected psyllids [1] [2]. Chlorpyrifos is an important tool to control Asian citrus psylla, and help prevent the establishment and spread of citrus greening in California.
- **Lorsban Advanced formulation technology reduces VOC emissions to less than half EC formulations of chlorpyrifos –** In California, all industries and sources of volatile organic compounds (VOC) are being required to reduce emissions to meet the ozone standards of the federal Clean Air Act. The CDPR has been working for several years to reduce pesticide VOC emissions by specified amounts to meet obligations under the 1994 State Implementation Plan. VOC issues have immediate ramifications at the grower level. In certain counties, growers are already limited in their product choices, their method of application, and their application timing with certain crop protection products. Emulsifiable Concentrate (EC) pesticide formulations are top contributors to nonfumigant pesticide VOC emissions in the San Joaquin Valley, and Lorsban Advanced has less than half the VOC emissions potential as EC formulations of chlorpyrifos. The advances in pesticide formulation technology used in Lorsban Advanced offer an additional benefit for citrus growers.

8.6 Chlorpyrifos Formulations, Rates, and Applications

The formulations of chlorpyrifos listed for controlling insect pests in citrus include Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG and Lorsban 15G.

Location: CA

- Pests: California red scale or citricola scale
- Product: Lorsban-4E, Lorsban Advanced
- Application Type: foliar
- Application Method: airblast sprayer
- Rate: 3.0-6.0 lb a.i./A
- Number of Applications: 1
- Season of Application: May-August

Location: CA

- Pests: foliar Lepidoptera (very limited use)
- Product: Lorsban-4E, Lorsban Advanced
- Application Type: foliar
- Application Method: airblast sprayer
- Rate: 2.0-3.0 lb a.i./A
- Number of Applications: 1
- Season of Application: May-August

Location: CA

- Pests: katydids (very limited use)
- Product: Lorsban-4E, Lorsban Advanced
- Application Type: foliar
- Application Method: airblast sprayer
- Rate: 0.5 lb a.i./A
- Number of Applications: 1
- Season of Application: May-August

Location: CA

- Pests: ant (grove floor or directed to trunk)
- Product: Lorsban-4E, Lorsban Advanced
- Application Type: ground and trunk
- Application Method: airblast sprayer
- Rate: 2.0-4.0 lb a.i./A
- Number of Applications: 1
- Season of Application: May-August

Location: FL

- Pests: Asian Citrus Psyllid
- Product: Lorsban-4E, Lorsban Advanced
- Application Type: foliar
- Application Method: airblast sprayer
- Rate: 2.35 lb a.i./A(Lorsban Advanced); 2.5 lb a.i./A Lorsban-4E

- Number of Applications: 1
- Season of Application: Jan-Dec

Location: FL

- Pests: foliar Lepidoptera (very limited use) for young trees
- Product: Lorsban-4E, Lorsban Advanced
- Application Type: foliar
- Application Method: airblast sprayer or hand gun on young trees
- Rate: 1.5 lb a.i./A Lorsban-4E
- Number of Applications: 1
- Season of Application: May-October

Location: FL

- Pests: katydids (very limited use)
- Product: Lorsban-4E, Lorsban Advanced
- Application Type: Foliar
- Application Method: Airblast sprayer
- Rate: 1.5 lb a.i./A
- Number of Applications: 1
- Season of Application: May-October

Location: FL

- Pests: ants (grove floor)
- Product: Lorsban-4E, Lorsban Advanced
- Application Type: ground and trunk
- Application Method: herbicide sprayer
- Rate: 1.0 lb a.i./A
- Number of Applications: 2
- Season of Application: May-November

Location: FL

- Pests: citrus rust mite
- Product: Lorsban-4E, Lorsban Advanced
- Application Type: foliar
- Application Method: airblast sprayer
- Rate: 2.5 lb a.i./A
- Number of Applications: 1
- Season of Application: April-June

Location: FL

- Pests: scale insects
- Product: Lorsban-4E, Lorsban Advanced

- Application Type: foliar
- Application Method: airblast sprayer
- Rate: 1.5 lb a.i./A
- Number of Applications: 2
- Season of Application: April-October

Location: FL

- Pests: mealy bugs
- Product: Lorsban-4E, Lorsban Advanced
- Application Type: foliar
- Application Method: airblast sprayer
- Rate: 2.0 lb a.i./A
- Number of Applications: 1
- Season of Application: April-May

Location: FL

- Pests: aphids
- Product: Lorsban-4E, Lorsban Advanced
- Application Type: foliar
- Application Method: airblast sprayer or hand gun on young trees
- Rate: 1.5 lb a.i./A
- Number of Applications: 0.5 of areas with young trees treated
- Season of Application: April-May

Location: FL

- Pests: grasshoppers
- Product: Lorsban-4E, Lorsban Advanced
- Application Type: foliar and ground
- Application Method: airblast sprayer or hand gun on young trees
- Rate: 2.0 lb a.i./A
- Number of Applications: 1
- Season of Application: August-October

Table 44. Leading Chemical Treatments for Insect Control in Citrus.

Note: Information in the "Benefits, Application, Use and Efficacy" section reflect opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, Lorsban 15G, others	-Highly efficacious against katydids, red and citricola scale, and also controls Asian citrus psyllid. -Chlorpyrifos is only viable solution in young trees where ant feeding can girdle a young tree in a few days. -Broad spectrum. -Relatively short residual. -Group 1B MOA for resistance management. -Cost effective.
Abamectin	Agri-Mek, others	-Controls Asian citrus psyllid, citrus rust mite and citrus leafminer. -Effective for broadcast application against ants, but is applied as a preventive treatment due to its slow action. - Group 6 MOA.
Cyfluthrin	Baythroid, others	-Primarily used for citrus thrips, katydid and Asian citrus psyllid control. -Toxic to vedalia beetle. -Group 3A MOA.
Fenpropathrin	Danitol	-Primarily used for Asian citrus psyllid, citrus rust mite and katydid control. -Toxic to vedalia beetle. -Group 3A MOA.
Imidacloprid	Several	-Primarily used for Asian citrus psyllid, leafminer and scale control. -Group 4A MOA.
Petroleum Oil	Several	-Moderately effective. -Not suitable for heavy infestation of scale. -Compatible with biocontrol. -High rates required in CA for California red scale making economics questionable. -Often tank mixed with chlorpyrifos or other insecticide in citrus.
Pyriproxyfen	Esteem	-Insect growth regulator (juvenoid) with good *Homoptera* activity. -Typically used in rotation with chlorpyrifos and has helped to prevent or minimize the resistance development in red scale to organophosphates. -Grower cost of this product is roughly 3X that of chlorpyrifos. -Does not control citricola scale -Highly toxic to vedalia beetle. -Group 7C MOA.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Spirotetramat	Movento	-Primarily used of Asian citrus psyllid, citrus rust mite and scale control. -Group 23 MOA.
Sulfoxaflor	Closer	-Controls plant bug, tarnished plant bug, Lygus bug, cotton aphid and whiteflies -Group 4C MOA.
Thiamethoxam	Actara	-Primarily used of leafminer, Asian citrus psyllid, and citrus rust mite control. -Group 4A MOA.
Zeta-Cypermethrin	Mustang, others	-Primarily used of leafminer, Asian citrus psyllid, and citrus rust mite control. -Toxic to vedalia beetle. -Group 3A MOA.

8.7 Non-Chemical Alternatives

Biocontrol is widely practiced in citrus production, particularly in the management of Homoptera pests (scales, mealybugs and aphids). The focus is to minimize the impact of pesticide sprays on biocontrol programs. Chlorpyrifos has been shown to be compatible with most of the biological control agents used in citrus.

8.8 Grower Perspective

In preparing this report, growers and crop consultants were asked to share their thoughts on the benefits and use of chlorpyrifos for pest control. Growers also commented during public comment periods in 2011 (EPA-HQ-OPP-2008-0850-0025) and 2015 (EPA-HQ-OPP-0850-0224).

"Chlorpyrifos knocks down citricola scale, a very hard to control scale in citrus that has no natural predators. It is effective on a wide range of pests including red scale, cutworms, and katydids. In granular form, Lorsban 15G offers excellent ant control. In the winter, we use a half gallon per acre of Lorsban for mealybug control in grapes." – Dennis McFarlin, Pest Control Advisor, Gar Tootelian, Inc., Reedley, CA (April 2009)

8.9 References

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9. Corn

9.1 Overview

Corn is the most widely produced feed grain in the U.S., accounting for more than 90% of the total value and production of feed grains. The number of acres of corn in the U.S. grew dramatically in 2012, increasing from an 80-90 million acres in 2004-2011 to a record of 97.3 million acres in 2012 [1]. Most of the crop is used as the main energy ingredient in livestock feed. Corn is also processed into a multitude of food and industrial products including starch, sweeteners, corn oil, beverage and industrial alcohol, and fuel ethanol. The U.S. is a major player in the world corn trade market, with approximately 20% of the corn crop exported to other countries. Eighty-seven percent of 2014 corn acres were grown in the Midwest and Plains states. Five states, Iowa, Illinois, Nebraska, Minnesota and Indiana, account for 54% of planted acres.

Table 45. U.S. Corn Production - Acres Planted 2012–2014.

Acres Planted (000)			
2012	2013	2014	2012-2014 Average
97,291	95,365	90,597	94,418

Source: USDA, NASS.

9.2 Growth in Insect Traits and Insecticide Seed Treatments in Corn

Above- and below-ground pests such as the corn rootworm, black cutworm, western bean cutworm, and European corn borer can destroy corn, minimizing the yield that a grower can produce on each acre of his farming operation. The economic impact of these pests can be devastating. The USDA estimates that corn rootworm causes more than $1 billion in lost revenue each year, which includes $800 million in yield loss and $200 million in treatment costs, making it the costliest pest in corn. Increased adoption of corn with insect-resistance traits and seed treatments which protect against a number of pests including the corn rootworm and European corn borer have greatly reduced the need to apply insecticides. NASS data show insect trait acres have grown from 30% of planted acres in 2004 to 80% in 2014, and insecticide seed treatments have grown from 9% of treated acres in 2004 to 94% in 2014. Soil applied insecticide treatments have declined from 30% to less than 10% of treated acres in 2014 in response to the increased use of genetic traits and insecticide seed treatments.

Growers who plant Bt (*Bacillus thuringiensis*) corn hybrids are required to implement an insect resistance management plan by planting a portion of "refuge" acres that do not have the Bt genes or by planting RIB (refuge-in-the-bag) corn products. Planting a refuge of non-Bt corn products helps decrease the natural selection pressures that can lead to insect resistance. These refuge acres ensure that rare resistant insects which feed on insect-protected varieties of corn will mate with susceptible insects and delay the development of resistance. Refuge corn can be treated with a non-Bt insecticide if insect pressure meets or exceeds the economic threshold.

9.3 Chlorpyrifos Use

Growers used an average of 636,856 lb a.i. of chlorpyrifos annually to control insect pests in corn in 2012-2014, a 76% reduction in the average annual use from 2003-2007 (2,617,433 lb a.i.). The significant reduction in chlorpyrifos use has resulted from increased planting of Bt corn and the use of insecticide seed treatments.

Table 46. Chlorpyrifos Use in Corn – Acres Treated and Lbs a.i. 2012–2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	911,247	876,938	548,147	778,777
Lbs a.i. Applied	795,268	712,380	402,920	636,856

Source: Proprietary third party data.

9.4 Target Pests

While the growth in popularity of Bt corn and insecticide seed treatments have changed growers' use of insecticides, chlorpyrifos continues to be used on corn refuge acres to control corn rootworm, Western bean cutworm, cutworm, and secondary pests. It is important to ensure that post-emergence insecticide treatments like chlorpyrifos remain available for use in the event of an insect pest outbreak.

Current low commodity prices are forcing many growers to alter their input purchase decisions. Some growers will purchase Bt corn with above-ground insect control, but no below-ground Bt trait, and use a soil insecticide to save $20-30 per acre by not purchasing the below-ground Bt trait. Similarly, some growers will purchase seed with the lowest insecticide seed treatment rate applied, and use a half-rate of soil insecticide to help control corn rootworm and protect against secondary soil insects such as seed corn maggot, seed corn beetle, wireworms, grubs. Chlorpyrifos is an excellent choice for these uses.

9.5 Benefits of Chlorpyrifos in Corn

- Effective control of the primary insect pests in corn including corn rootworm (larvae and adult), seed corn maggot, white grubs, wireworm, corn earworm, armyworms and cutworm.
- Broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Effective rotation partner for resistance management – offers a Group 1B mode of action to use on refuge acres and to rotate with other insecticides to help manage resistance development.
- Cost effective.

9.6 Chlorpyrifos Formulations, Rates, and Applications

Formulations typically used for controlling insect pests in corn are Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban 15G (and other chlorpyrifos granular formulations), Lorsban Advanced, Lorsban 75WG, Cobalt, and Cobalt Advanced.

Location: Midwest, Plains and Atlantic

- Pest: armyworm, cutworms
- Application Type: ground, air, chemigation
- Application Method: broadcast
- Rate: 0.5 – 1.0 lb a.i./A (EC)
- Number of Applications: 1
- Timing of Applications: preplant, at-plant, preemergence

Location: Midwest, Plains and Atlantic

- Pest: grasshoppers
- Application Type: ground, air, chemigation
- Application Method: post application
- Rate: 0.25 – 0.5 lb a.i./A (EC)
- Number of Applications: 1
- Timing of Applications: post to corn emergence

Location: Midwest and Plains

- Pest: armyworm, cutworms, aphids, rootworm adults, European corn borer, flea beetle
- adults, southern corn leaf beetle, webworms, western bean cutworm
- Application Type: ground, air, chemigation
- Application Method: broadcast
- Rate: 0.5 – 1.0 lb a.i./A (EC)
- Number of Applications: 1
- Timing of Applications: post to corn emergence

Location: Midwest, Plains and Atlantic

- Pest: armyworm, cutworms, aphids, European corn borer, flea beetle adults, webworms
- Application Type: ground, air, chemigation
- Application Method: broadcast
- Rate: 0.5 – 1.0 lb a.i./A (EC)
- Number of Applications: 1
- Timing of Applications: post to corn emergence

Location: Midwest, Plains and Atlantic

- Pest: corn earworm
- Application Type: ground, air, chemigation
- Application Method: broadcast
- Rate: 0.75 – 1.0 lb a.i./A (EC)
- Number of Applications: 1
- Timing of Applications: post to corn emergence

Location: Midwest and Plains

- Pest: rootworm larvae, lesser cornstalk borer, common stalk borer
- Application Type: ground, air, chemigation
- Application Method: broadcast
- Rate: 1.0 lb a.i./A (EC)
- Number of Applications: 1
- Timing of Applications: post to corn emergence

Location: Midwest, Plains and West

- Pest: rootworms, cutworms, wireworm, lesser seed corn borer, billbugs
- Application Type: ground
- Application Method: at plant
- Rate: 1.30 lb a.i./A (granular)
- Number of Applications: 1
- Timing of Applications: at planting

Location: Midwest and Plains

- Pest: European corn borer
- Application Type: aerial, ground
- Application Method: broadcast or directed
- Rate: 0.75 – 1.0 lb a.i./A (granular)
- Number of Applications: 1
- Timing of Applications: in relation to corn growth from V9 to R1

9.7 <u>References</u>

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10. Cotton

10.1 Overview

An average of 11.2 million acres of cotton was grown annually in the U.S. in 2012-2014. Nearly 96% of U.S. cotton was grown in the Southern and Plains states, and approximately 450,000 acres were grown in California and Arizona. Most of the California cotton is produced in the San Joaquin Valley. Since 2000, losses due to insect pests in cotton nationwide have remained below 5% [1]. This is attributed to the boll weevil eradication and widespread use of transgenic (Bt) cotton varieties. Over 90% of U.S. cotton acreage was planted with transgenic crop varieties.

Table 47. U.S. Cotton Production – Acres Grown 2012-2014.

State	Acres Grown			
	2012	2013	2014	2012-2014 Average
TEXAS	6,812,970	5,759,069	6,217,000	6,263,013
GEORGIA	1,249,984	1,359,997	1,380,000	1,329,994
NORTH CAROLINA	550,009	464,990	465,000	493,333
MISSISSIPPI	579,994	300,000	425,000	434,998
ARKANSAS	580,004	304,990	330,000	404,998
ALABAMA	389,998	364,998	355,000	369,999
TENNESSEE	379,999	250,000	270,000	300,000
MISSOURI	375,002	250,002	250,000	291,668
CALIFORNIA	365,000	279,994	215,000	286,665
SOUTH CAROLINA	280,001	255,000	280,000	271,667
OKLAHOMA	329,997	185,000	230,000	248,332
LOUISIANA	230,000	130,004	170,000	176,668
ARIZONA	204,002	156,500	155,000	171,834
FLORIDA	115,000	130,001	105,000	116,667
KANSAS	54,999	27,000	30,000	37,333
U.S. Total	**12,496,957**	**10,217,546**	**10,876,999**	**11,197,168**

Source: Proprietary third party data.

10.2 Chlorpyrifos Use

Although chlorpyrifos use in cotton only averaged 1.7% of all active ingredient acres treated on this crop in 2012-2014, it is an important tool in U.S. cotton production systems. Growers used an average of 105,584 lb a.i. of chlorpyrifos annually to control insect pests in cotton in 2012-2014, a 35% decrease in average annual use from 2003-2007 (161,692 lb a.i.). Chlorpyrifos was one of the most-used active ingredients for controlling stink bug (green and brown), tarnished plant bug and Lygus bug in cotton. Maintaining the availability of chlorpyrifos in the cotton insecticide complex is important for the effective control of these insect pests and the viability of long-term resistance management programs.

Table 48. Chlorpyrifos Use in Cotton – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	269,433	359,410	420,899	349,914
Lb a.i. Applied	84,106	120,978	111,668	105,584

Source: Proprietary third party data.

Four states, Arizona, California, Georgia and Texas, accounted for over 98% of the chlorpyrifos used in 2012-2014. Over 81% was used in Georgia and Texas and 17.4% was used in Arizona and California to control insect pests in cotton.

Table 49. Chlorpyrifos Use in Cotton by State – Acres Treated 2012-2014.

State	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
GEORGIA	--	280,606	386,972	222,526	63.6%
TEXAS	178,489	4,647	4,158	62,431	17.8%
CALIFORNIA	78,933	72,711	12,568	54,737	15.6%
ARIZONA	12,011	--	6,430	6,147	1.8%
ALABAMA	--	--	8,114	2,705	0.8%
KANSAS	--	1,447	2,106	1,184	0.3%
LOUISIANA	--	--	551	184	0.1%
U.S. Total	**269,433**	**359,410**	**420,899**	**349,914**	**100.0%**

Source: Proprietary third party data.

Some variation in acres treated and lbs a.i. applied were found comparing CDPR and proprietary third party data for chlorpyrifos use in cotton.

Table 50. Chlorpyrifos Use in California Cotton – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	Data Source	2012	2013	2014	2012-2014 Average
Acres Treated	CDPR	78,933	72,711	12,568	54,737
	Proprietary third party	56,500	35,963	63,441	51,968
Lb a.i. Applied	CDPR	96,150	156,526	92,254	114,977
	Proprietary third party	59,200	52,646	8,718	40,188

10.3 Target Pests

Stink bug (including brown, green, southern green), plant bug (including tarnished plant bug), thrips and boll worm are the primary insect pests of cotton in the Plains and Southern regions.

Table 51. Top Insect Pests in Plains and Southern Regions Cotton – Acres Treated 2012-2014.[1]

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
BUG, PLANT	8,080,061	3,898,663	6,832,109	6,270,278	32.1%
BUG, STINK	4,216,588	2,954,477	3,921,515	3,697,526	18.9%
THRIP	3,352,850	2,553,733	3,485,007	3,130,530	16.0%
WORM, BOLL	2,016,584	1,226,136	2,388,526	1,877,082	9.6%
BUG, BROWN STINK	1,454,815	2,253,979	1,751,210	1,820,001	9.3%
BUG, GREEN STINK	1,647,109	2,200,522	1,235,582	1,694,404	8.7%
BUG, TARNISHED PLANT	1,843,071	1,792,338	1,000,874	1,545,428	7.9%
U.S. Total	**30,174,291**	**21,890,473**	**28,290,522**	**26,785,095**	Column Total **102.7%**

Source: Proprietary third party data. Excluding seed treatments.
[1] USDA Farm Production Regions.

Lygus bug, whiteflies, aphids and mites are the primary insect pests in cotton in the West.

Table 52. Top Insect Pests in Arizona and California Cotton – Acres Treated 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
BUG, LYGUS	502,459	762,545	344,304	536,436	44.8%
WHITEFLY	277,939	156,859	57,465	164,088	13.7%
APHID	269,706	132,041	72,782	158,176	13.2%
MITE, SPIDER	42,120	212,576	107,168	120,621	10.1%
MITE, 2-SPOTTED	189,975	51,008	58,263	99,749	8.3%
BUG, PLANT	99,289	41,196	68,351	69,612	5.8%
APHID, COTTON	18,045	127,302	24,086	56,478	4.7%
U.S. Total	**1,691,607**	**1,807,832**	**946,238**	**1,481,892**	Column Total **100.7%**

Source: Proprietary third party data. Excluding seed treatments.

10.3.1 Lygus Bug, Plant Bug and Stink Bug

Nationally, Lygus was the No. 1 pest of cotton in 2013, according to entomologists, causing 0.788% in losses [1]. In the Mid-South, Mississippi, Arkansas and Missouri reported losses exceeded 4%. About 37% of the acres in the U.S. are infested with Lygus. Stink bugs were second at 0.681% loss and thrips were third, reducing yields by 0.557%. About 54% of U.S. cotton acres are infested with stink bugs. Populations of stink bugs and plant bugs are generally heavier in the Plains and Southern states, while Lygus bug populations are generally more prevalent in the west. The average number of sprays for stink bugs was two per acre with a range of zero to four applications per field in Georgia in 2013 [2].

10.3.2 Silverleaf Whitefly

Silverleaf whitefly is a major problem in cotton in California, Arizona and Texas, and an occasional pest of cotton in the Southern states. Silverleaf whitefly problems develop from populations that overwinter in cole crops, ornamentals, and weeds. Populations often build in spring melons and migrate to cotton. This insect produces honey dew that causes widespread sticky cotton problems. Sticky cotton can reduce gin output (in bales/hour) by up to 25%. At the textile mill, excessive wear and increased maintenance may occur even in slightly sticky cotton. In severe instances mill shutdown with a thorough cleanup is required. Regional penalties for stickiness are estimated at $0.03-0.05 per pound for Arizona following the whitefly outbreak of 1992. Similar market penalties can be re-imposed in any region should the potential for stickiness be suspected. Silverleaf whitefly was estimated to infest approximately 710,000 acres of cotton in the U.S. with estimated yield losses of 4,870 bales or approximately $1.9 million in 2014 [1]. Infested acres averaged 1.6 insecticide treatments per crop to control this aggressive pest in 2014, which is higher than the number of treatments used to control other insects that infest cotton.

10.3.3 Cotton Aphid

Cotton aphids are a primary pest of cotton in the West. A naturally occurring fungus, *Neozygites fresenii*, suppresses aphid populations in the Plains and Southern regions, and aphids rarely require treatment. Feeding by high populations of aphids may result in stunting and poor growth, and may reduce yields. As they feed, aphids 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. The information and comments regarding "sticky cotton" and whiteflies also applies to aphids. Aphids were estimated to infest approximately 5.0 million acres of cotton or 45% of the planted U.S. acreage (11.0 million acres) in 2014 [1]. Yield losses from aphids were estimated at 8,399 bales or approximately $3.3 million in 2014.

Chlorpyrifos was the third most-used active ingredient to control stink bugs, plant bugs and Lygus bugs in cotton in Georgia and Texas, and was used on 7.5% of the pest acres treated for these insects in 2012-2014. Chlorpyrifos was also used to control spider mites, armyworm and soybean looper in these states.

Table 53. Leading Insecticide Active Ingredients Used in to Control Stink Bugs, Plant Bugs and Lygus Bugs in Georgia and Texas Cotton – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
DICROTOPHOS	2,144,850	2,713,055	3,315,323	2,724,409	49.9%
BIFENTHRIN	1,638,630	1,246,530	1,449,859	1,445,006	26.5%
CHLORPYRIFOS	350,224	424,585	457,556	410,788	7.5%
IMIDACLOPRID	377,228	60,683	217,571	218,494	4.0%
ZETA-CYPERMETHRIN	91,469	194,445	159,412	148,442	2.7%
U.S. Total	**4,922,331**	**5,013,846**	**6,451,865**	**5,462,681**	**Column Total 90.6%**

Source: Proprietary third party data. Excluding seed treatments.

Chlorpyrifos, also was the third most-used active ingredient to control whiteflies, aphids, Lygus bugs, stink bugs and plant bugs in cotton in Arizona and California, and was used on 8.8% of the pest acres treated for these insects in 2012-2014. The number of chlorpyrifos treated acres that targeted control of whiteflies and aphids, was approximately four times the number of acres treated for Lygus, plant and stink bug control in 2012-2014.

Table 54. Leading Insecticide Active Ingredients Used to Control Whiteflies, Aphids, Lygus Bug, Plant Bug and Stink Bug in Arizona and California Cotton – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
FLONICAMID	276,145	353,910	157,857	262,637	25.0%
ACETAMIPRID	149,106	128,235	28,292	101,878	9.7%
CHLORPYRIFOS	155,525	100,007	21,434	92,322	8.8%
IMIDACLOPRID	22,795	128,799	78,206	76,600	7.3%
BIFENTHRIN	30,484	146,254	15,990	64,243	6.1%
OXAMYL	63,210	70,871	31,742	55,274	5.3%
NALED	143,514	18,965		54,160	5.2%
U.S. Total	**1,197,614**	**1,370,516**	**578,582**	**1,048,904**	**Column Total 67.4%**

Source: Proprietary third party data. Excluding seed treatment.

10.4 Benefits of Chlorpyrifos in Cotton

- Effective control of several of the primary insect pests in cotton including Lygus bug, plant bug, stink bug, silverleaf whitefly and aphids, as well as other economically important insect pests such as spider mites, armyworm and soybean looper.
- Broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests. Pyrethroids are effective for control of green stick bug and southern green stink bug, but are only fair against brown stink bug. Chlorpyrifos is effective on all three species.
- Significantly less disruptive to beneficial populations than the pyrethroids, and does not flare aphids and whiteflies.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance. Whiteflies, aphids, Lygus bugs, stink bugs and plant bugs have developed resistance to several classes of insecticides. The availability of chlorpyrifos allows growers to rotate between different insecticide modes of action, which helps delay resistance development in all insecticides.
- Cost effective.

10.5 Chlorpyrifos Formulations, Rates, and Applications

The formulations listed for controlling insect pests in cotton include Lorsban-4E (and other 4 lbs per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Cobalt, Cobalt Advanced, and Lock-On.

Location: California, Arizona

- Pests: whiteflies, cotton aphid, Lygus bug, beet armyworm, thrips
- Application Type: foliar
- Application Method: ground and air
- Rate: 0.5-1.0 lb a.i./A
- Number of Applications: whiteflies (3), cotton aphid (3), Lygus (3), armyworms (2)
- Season of Application: aphids and armyworms – July to September; Lygus and whiteflies – July to August

Location: Arkansas, Alabama, Florida, Georgia, Kansas, Louisiana, Missouri, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas (not for use in Mississippi)

- Pests: stink bug, plant bug, spider mites, armyworm, soybean looper, cotton aphid, armyworm, spider mites
- Application Type: foliar
- Application Method: ground and air
- Rate: 0.5-1.0 lb a.i./A

- Number of Applications: stink bug/plant bug (2), spider mites (2), armyworms (2)
- Season of Application: stink bug/plant bug – July to August; armyworms – July to September

Table 55. Leading Chemical Treatments for Insect Control in Cotton.

Note: Information in the "Application, Use and Efficacy" section reflect opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, others	-Controls all species of stink bug, plant bug and Lygus bug. -Also controls whiteflies, aphids, Lepidoptera species, spider mites and other insect pests. -Broad spectrum. -Group 1B MOA for resistance management. -Cost effective.
Chlorpyrifos + Gamma-Cyhalothrin	Cobalt Insecticide, Cobalt Advanced	-Controls all species of stink bug, plant bug and Lygus bug -Also controls whiteflies, aphids, Lepidoptera species, spider mites and other insect pests. -Broad spectrum. -Groups 1B and 3A MOA for resistance management.
Acetamiprid	Assail	-Controls aphid, whiteflies, Lygus bug and thrips. -Group 4A MOA.
Bifenthrin	Capture, others	-Controls stink bug, plant bug and Lygus bug, however, is less effective on brown stink bug. -Also controls whiteflies, aphids, Lepidoptera species and other insect pests. -Broad spectrum. -Disruptive to beneficial populations and may flare aphids and whiteflies. -Group 3A MOA.
Dicrotophos	Bidrin, others	-Controls stink bug, plant bug and Lygus bug. -Does not control Lepidoptera species and only offers suppression of spider mites and aphids. -Group 1B MOA.
Flonicamid	Carbine	-Controls Lygus bug, cotton fleahopper and

Active Ingredient	Brand Names	Application, Use, and Efficacy
		cotton aphid. -Does not control spider mites or Lepidoptera species. -Group 29 MOA.
Imidacloprid	Several	-Controls stink bugs and plant bugs in the Plains and Southern states and aphids. -Only provides suppression of whiteflies and Lygus bug in the West. -Group 4A MOA.
Zeta-Cypermethrin	Mustang, others	-Controls stink bug, plant bug and Lygus bug, however, is less effective on brown stink bug. -Also controls whiteflies, aphids, Lepidoptera species and other insect pests. -Broad spectrum. -Disruptive to beneficial populations and may flare aphids and whiteflies. -Group 3A MOA.

10.6 Non-Chemical Alternatives

Alfalfa is a preferred host of Lygus bug, and can be managed to minimize movement of Lygus bugs into cotton by staggering cuttings to preserve alfalfa habitat. Cotton should be planted at least one-half mile upwind from other key whitefly hosts such as melons, cole crops, and tomatoes. Good sanitation should be maintained in areas of winter and spring host crops and weeds by destroying and removing all crop residues as soon as possible. Control weeds in non-crop areas including head rows and fallow fields, and harvest alfalfa on as short a schedule as possible. Acala varieties, which require less time to mature than Pima varieties, may have fewer whitefly infestations. In general, all Pima varieties are more attractive to silverleaf whitefly than upland cotton varieties. Hairy-leaf upland cotton varieties are more susceptible than smooth-leaf varieties.

Higher cotton aphid numbers develop on late-planted cotton when compared to early-planted cotton. Aphids prefer cotton plants that are well watered and highly fertilized. Poorly scheduled or excessive nitrogen applications that stimulate growth later in the cropping season are more susceptible to aphids. Pima cultivars appear to be more susceptible to aphid infestations and associated damage. Hairy-leaf Acala varieties are more susceptible to aphids than smooth-leaf varieties.

10.7 Grower Perspective

In late 2007, the EPA asked for public comments on issues related to the agricultural use of chlorpyrifos. The following is an excerpt from a grower organization that responded to the EPA's request for input by explaining why they considered chlorpyrifos essential for protecting their crops. Submissions to the docket are public information, and have been posted by the EPA at www.regulations.gov, docket number EPA-HQ-OPP-2007-1005. Growers also commented during public comment periods in 2011 (EPA-HQ-OPP-2008-0850-0025) and 2015 (EPA-HQ-OPP-0850-0224).

"Chlorpyrifos in cotton is used primarily against cotton aphids, and particularly late-season infestations. These infestations are potentially very damaging in terms of sticky cotton. Chlorpyrifos is a highly effective chemical and one we can ill afford to lose." – California Cotton Ginners and Growers Association

10.8 **References**

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11. Cranberries

11.1 Overview

An average of 40,933 acres of cranberries were grown annually in the U.S. in 2012-2014. About half of the cranberry acres were grown in Wisconsin, 39% were grown in the Northeast region, and the remaining 11% were grown in the Pacific Northwest.

Table 56. U.S. Cranberry Production – Acres Grown 2012-2014.

State	Acres Grown			
	2012	2013	2014	2012-2014 Average
Wisconsin	19,700	21,100	20,400	20,400
Massachusetts	13,000	13,200	12,400	12,867
New Jersey	3,000	3,000	3,0009	3,000
Oregon	2,900	3,000	3,000	2,967
Washington	1,700	1,700	1,700	1,700
U.S. Total	**40,300**	**42,000**	**40,500**	**40,933**

Source: USDA, NASS.

11.2 Chlorpyrifos Use

No information was available on the number of treated acres or lb a.i. of chlorpyrifos applied on cranberries. University insect management recommendations indicate that chlorpyrifos was used on cranberries to control several primary insect pests including cranberry weevil, cranberry fruitworm, sparganothis fruitworm, cutworms, fireworms and spanworms.

11.3 Target Pests

Several insect pests must be managed to prevent economic damage to the cranberry crop. Insecticide management is extremely important, especially to prevent damage from direct fruit pests [1]. The relative importance of various insect species varies by growing region:

- **Northeast** – Cranberry weevil, cranberry fruitworm, sparganothis fruitworm, blackheaded fireworm and spotted fireworm are primary insect pests in cranberry in the Northeast. Cutworms, spanworms and gypsy moth also can cause economic damage [2].
- **Wisconsin** – Blackheaded fireworm, cranberry fruitworm and sparganothis fruitworm are primary insect pests in cranberries in Wisconsin. Spanworms and cranberry girdler are of secondary importance [3].

- **Northwest** – Blackheaded fireworm, cranberry fruitworm, cranberry girdler, blackvine weevil, cranberry tipworm and cutworm are primary insect pests in the Northwest [4].

Chlorpyrifos was one of the most important insecticides for cranberry production at the start of the last decade. At that time, chlorpyrifos was the only insecticide that would control sparganothis fruitworm and cranberry weevil in Massachusetts [1].

"Without this insecticide, these two insects would devastate the crop. If the four major insecticides chlorpyrifos, diazinon, azinphos-methyl and acephate were no longer available, growers would have to rely on other insecticides that may only provide fair to adequate control, or attempt to use less effective and/or more expensive specific cultural or biological alternatives for certain pests. However, there are no alternatives for most direct pests, such as the cranberry fruitworm and second generation blackheaded fireworm. In most places, yields would be significantly reduced since the remaining insecticides are not as effective and cultural or biological alternatives do not provide as good or as fast control as the chemicals. At least half of the crop could be lost to direct pests alone the first year in East Coast beds, with yield reductions of 15 to 50 percent estimated elsewhere. In subsequent years, pest pressure would be higher and losses more severe, enough to drive many growers out of business [1]."

Since then, several new insecticides have been labeled for use in cranberry to control these and other insect pests, however, chlorpyrifos remains an important insect management tool in cranberry. Maintaining the availability of chlorpyrifos in the cranberry insecticide complex is important for control of cranberry weevil, cranberry fruitworm, sparganothis fruitworm, and other primary insect pests, and viability of long-term resistance management programs.

11.4 Benefits of Chlorpyrifos in Cranberry

- Effective control of cranberry weevil, cranberry fruitworm, sparganothis fruitworm, cutworms, fireworms and spanworms.
- Broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.
- Cost effective.

11.5 Chlorpyrifos Formulations, Rates, and Applications

Current chlorpyrifos formulations listed for controlling insect pests in cranberries include Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG.

Location: MA, NJ, OR, WA, WI

- Product: Lorsban-4E, Lorsban Advanced or Lorsban 75WG
- Pests: cranberry weevil, cranberry fruitworm, sparganothis fruitworm, cutworms, fireworms and spanworms
- Application Type: ground or chemigation
- Application Method: broadcast
- Rate: 1.5 lb a.i./A
- Number of applications: 2
- Timing of Application: for cranberry weevil control, apply one at flower bud development (late May or early June), and if cranberry weevils are present, once after 100% bloom (early to mid-July)

Table 57. Leading Chemical Treatments for Insect Control in Cranberries.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, others	-Controls cranberry weevil, cranberry fruitworm, sparganothis fruitworm, cutworms, fireworms and spanworms. -Broad spectrum. -Group 1B MOA for resistance management. -Cost effective.
Burholderia species cells	Venerate XC	-Controls armyworms, fireworms, leafrollers, loopers and sparganothis fruitworm. -Suppresses cranberry weevil, aphids, mites and thrips. -Biological insecticide and miticide. -Approved for certified organic crop use.
Chromobacterium subtsugae	Grandevo	-Controls cranberry weevil, cranberry fruitworm, sparganothis fruitworm, cutworms, fireworms, spanworms, armyworms, leafrollers, loopers, mites, aphids and thrips. -Broad spectrum. -Biological insecticide and miticide. -Approved for certified organic crop use.
Clothianidin	Bely	-Controls cranberry weevil, cranberry fruitworm, sparganothis fruitworm, cranberry tipworm, blackheaded fireworm and flea beetle. -Broad spectrum. -Valent will discontinue the use of Belay on cranberry, but it will still be available in 2016 and 2017.

Active Ingredient	Brand Names	Application, Use, and Efficacy
		-Group 4A MOA.
Dinotefuran	Venom	-Controls flea beetles, leafhoppers and stink bugs. -Suppresses cranberry weevil, cranberry fruitworm, sparganothis fruitworm, cranberry tipworm, blackheaded fireworm and spanworm. -Group 4A MOA.
Indoxacarb	Avaunt	-Controls cranberry weevil, blackheaded fireworm and spanworms. -Group 22A MOA.
Thiamethoxam	Actara	-Controls cranberry weevil, cranberry flea beetle, Japanese beetle, leafhoppers and aphids. -Group 4A MOA.

Source: [4].

11.6 Non-Chemical Alternatives

Late water floods (April 15-May 15) may be used to manage cutworms, gypsy moth and cranberry fruitworm. Summer floods (May 12-June 20) may be used to eliminate grubs. Harvest and fall floods may be used to manage cranberry girdler, and suppress black vine weevil and strawberry weevil. Sanding on a regular basis suppresses cranberry girdler, green spanworm and cranberry tipworm.

11.7 References

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12. Filberts (hazelnuts)

12.1 Overview

An average of 35,141 acres of filberts were grown annually in the U.S. in 2012-2014. All of the commercial acreage was grown in Oregon.

Table 58. U.S. Filbert Production – Acres Grown 2012-2014.

State	Acres Grown			
	2012	2013	2014	2012-2014 Average
OREGON	34,132	34,132	37,159	35,141
U.S. Total	34,132	34,132	37,159	35,141

Source: Proprietary third party data.

12.2 Chlorpyrifos Use

Chlorpyrifos was one of the four most-used insecticide active ingredients to control insect pests in filberts, and was used on 7.6% of total treated acres in 2012-2014.

Table 59. Leading Insecticide Active Ingredients Used in Filberts – Acres Treated 2012–2014.

Insecticide	Acres Treated				% of Total a.i. Acres Treated (2012-2014
	2012	2013	2014	2012-2014 Average	
ESFENVALERATE	30,915	24,187	33,879	29,660	57.4%
CYFLUTHRIN	9,286	8,553	7,643	8,494	16.5%
IMIDACLOPRID	5,736	5,037	3,384	4,719	9.1%
CHLORPYRIFOS	3,885	4,049	3,850	3,928	7.6%
PETROLEUM OIL	3,640	1,977	2,088	2,568	5.0%
U.S. Total	**55,734**	**44,212**	**54,952**	**51,633**	**Column Total 95.6%**

Source: Proprietary third party data.

Growers used an average of 4,389 lb a.i. of chlorpyrifos annually to control insect pests in filberts in 2012-2014, a decrease of 40% from average annual use in 2003-2007 (7,286 lb a.i.). Chlorpyrifos was primarily used to control leafrollers, filbert worm and aphids. Maintaining the availability of chlorpyrifos in the filbert insecticide complex is important for control of these insect pests, and the viability of long-term resistance management programs.

Table 60. Chlorpyrifos Use in Filberts – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	3,885	4,049	3,850	3,928
Lbs a.i. Applied	5,083	3,869	4,217	4,389

Source: Proprietary third party data.

12.3 Target Pests

Filbert worm, aphids, and leafrollers were the top target pests in filberts, and accounted for 110.2% of the total active ingredient acres. Each causes significant losses in filberts as described below. Chlorpyrifos provides broad spectrum control of a number of insect pests in filberts, and was the insecticide active ingredient most-used to control leafrollers.

Table 61. Top Insect Pests in Filberts – Acres Treated 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
WORM, FILBERT	36,558	31,234	41,369	36,387	70.5%
APHID	15,912	12,162	3,273	10,449	20.2%
LEAFROLLER, FILBERT	5,529	14,243	5,432	8,401	16.3%
WORM	--	6,947	--	2,316	4.5%
MITE	2,679	1,038	2,120	1,946	3.8%
LEAFROLLER, OBLIQUEBANDED	--	1,661	3,360	1,674	3.2%
LEAFROLLER	721	692	1,563	992	1.9%
U.S. Total	**869,824**	**1,075,608**	**1,291,430**	**1,078,954**	**120.4%**

Source: Proprietary third party data.

12.3.1 Leafrollers

The filbert leafroller and obliquebanded leafroller are both primary insect pests of filberts. Filbert leafroller larvae hatch in early spring and feed on buds reducing nut yields, and destroying buds that would later develop into nuts. This insect has only one generation per year while the obliquebanded leafroller has two generations per year. First generation obliquebanded leafroller larvae become active in early spring, and feed on buds and leaves which may reduce yield by destroying nut buds. Second generation larvae are active in July and feed primarily on leaves, but small larvae may also feed under the husk on the developing nut. This feeding injury causes premature nut drop and occasionally produces substantial yield losses [1].

Chlorpyrifos was the insecticide active ingredient most-used to control filbert and obliquebanded leafrollers, and was used on 33.3% of the pest acres treated for leafroller control in 2012-2014.

Table 62. Leading Insecticide Active Ingredients Used to Control Leafrollers in Filberts – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CHLORPYRIFOS	3,685	2,936	4,446	3,689	33.3%
CYFLUTHRIN	894	4,828	1,813	2,512	22.7%
IMIDACLOPRID	894	4,828	1,813	2,512	22.7%
ESFENVALERATE	777	3,658	1,806	2,080	18.8%
CHLORANTRANILIPROLE	--	346	477	274	2.5%
U.S. Total	**6,250**	**16,596**	**10,356**	**11,067**	**100.0%**

Source: Proprietary third party data.

12.4 Benefits of Chlorpyrifos in Filberts

- Chlorpyrifos is the insecticide most used for leafroller control in filberts.
- Effective control of several primary insects pests of filberts including filbert leafroller, obliquebanded leafroller, filbert worm and aphids as well as other economically important insect pests.
- Provides broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.
- Cost effective.

12.5 Chlorpyrifos Formulations, Rates, and Applications

The formulations listed for controlling insect pests in filberts include Lorsban-4E (and other 4 lbs per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, Cobalt and Cobalt Advanced.

Location: OR

- Pests: filbert leafroller, obliquebanded leafroller, filbert worm, aphids, eye-spotted bud moth, omnivorous leaftier, winter moth
- Application Type: foliar
- Application Method: ground
- Rate: 1.5-2.0 lb a.i./A

- Number of Applications: 1-2
- Season of Application: spring and/or summer

Table 63. Leading Chemical Treatments for Insect Control in Filberts.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, others	-Controls filbert leafroller, obliquebanded leafroller, filbert worm, aphids and other insect pests. -The insecticide most used for leafroller control. -Broad spectrum. -Group 1B MOA for resistance management -Cost effective.
Chlorpyrifos + Gamma-Cyhalothrin/ Chlorpyrifos + Lambda-Cyhalothrin	Cobalt/ Cobalt Advanced	-Controls filbert leafroller, obliquebanded leafroller, filbert worm, aphids and other insect pests. -Broad spectrum. -Group 1B and 3A MOA for resistance management -Cost-effective
Cyfluthrin	Baythroid	-Controls filbert leafroller, obliquebanded leafroller and filbert worm. -Group 3A MOA.
Esfenvalerate	Asana	-Controls filbert leafroller, obliquebanded leafroller and filbert worm. -Group 3A MOA.
Imidacloprid	Several	-Controls aphids. -Group 4A MOA.
Methoxyfenozide	Intrepid	-Controls filbert leafroller, obliquebanded leafroller and filbert worm. -Insect growth regulator. -Group 18 MOA.
Spinetoram	Radiant	-Controls filbert leafroller, obliquebanded leafroller and filbert worm. -Group 5 MOA.
Spinosad	Entrust	-Controls filbert leafroller, obliquebanded leafroller and filbert worm. -Approved for certified organic crop use. -Group 5 MOA.

Source: [1].

12.6 Non-Chemical Alternatives

Naturally occurring beneficial insects (parasitoids) may keep the early population of leafrollers under control, and pesticide applications are not necessary. No cultural controls are available.

12.7 University Entomologist Perspective

University researchers and extension workers identified the following "critical need" in the *Pest Management Strategic Plan for Hazelnuts in Oregon and Washington* [1]. Growers also commented during public comment periods in 2011 (EPA-HQ-OPP-2008-0850-0025) and 2015 (EPA-HQ-OPP-0850-0224).

Summary of Critical Needs – Regulatory

- "Retain the registration of chlorpyrifos (Lorsban and other brands), which plays a unique and important role in insect pest management in hazelnut orchards. *[Chlorpyrifos controls]...insects that are difficult to control due to their habit of protecting themselves in rolled leaves, such as leafroller larvae.*"

12.8 References

1. DeFrancesco, J., and D. Clarke. Western Integrated Pest Management Center. *Pest Management Strategic Plan for Hazelnuts in Oregon and Washington. Summary of a workshop held on November 29, 2006.* 2006. http://www.ipmcenters.org/pmsp/pdf/ORWA_Hazelnut. Accessed December 29, 2015.

13. Grapes

13.1 Overview

The U.S. wine, grape, and grape products' industries contribute more than $162 billion annually to the American economy [1]. An average of 1,031,580 acres of grapes was grown in the U.S. in 2012-2014 (USDA, NASS). U.S. grape and grape products industries are largely concentrated in California which accounted for nearly 84% of the total grape acreage, including virtually all table grapes and raisins, and roughly 90% of the nation's wine production. Almost all U.S. raisins are produced in California's San Joaquin Valley. Washington, New York and Michigan grew 6.7%, 3.5% and 1.7% of the U.S. grape acreage, respectively, and the rest of the states grew 4.6% combined.

Table 64. U.S. Grape Production – Acres Grown 2012-2014.

State	Type of Grape	Acres Grown			
		2012	2013	2014	2012-2014 Average
California	Raisin	230,234	230,234	217,424	225,964
	Table	93,737	93,737	119,583	102,352
	Wine	551,286	551,286	619,660	574,077
	Total	**875,257**	**875,257**	**956,667**	902,394
New York	Table	566		3,581	1,382
	Wine	41,978	42,544	35,721	40,081
	Total	**42,544**	**42,544**	**39,302**	41,463
U.S. Total		**917,801**	**917,801**	**995,969**	**943,857**

Source: Proprietary third party data. No data reported for Washington, Michigan or other states.

13.2 Chlorpyrifos Use

Although chlorpyrifos use in grapes only averaged 2.2% of all active ingredient acres treated on this crop in 2012-2014, it is an important tool in U.S. grape production systems. Growers used an average of 82,846 lb a.i. of chlorpyrifos annually to control insect pests in grapes in 2012-2014, a 55% decrease in average annual use from 2003-2007 (186,148 lb a.i.). Chlorpyrifos was primarily used for control of mealybugs in grapes. Maintaining the availability of chlorpyrifos in the grape insecticide complex is important for the control of this pest and viability of long-term resistance management programs.

Table 65. Chlorpyrifos Use in Grapes – Acres Treated and Lb. a.i. Applied 2012-2014.

Crop	Data	2012	2013	2014	2012-2014 Average
Raison Grapes	Acres Treated	12,721	7,336	15,417	11,825
	Lbs a.i. Applied	22,323	14,859	29,340	22,174
Table Grapes	Acres Treated	33,373	23,674	36,929	31,325
	Lbs a.i. Applied	38,033	32,505	59,824	43,454
Wine Grapes	Acres Treated	10,407	4,953	11,095	8,818
	Lbs a.i. Applied	18,969	9,864	22,822	17,218
U.S. Total	**Acres Treated**	**56,501**	**35,963**	**63,441**	**51,968**
	Lbs a.i. Applied	**79,325**	**57,228**	**111,986**	**82,846**

Source: Proprietary third party data.

Some variation in acres treated and lbs a.i. applied were found comparing CDPR and proprietary third party data for chlorpyrifos use in cotton.

Table 66. Chlorpyrifos Use in California Grapes – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	Data Source	2012	2013	2014	2012-2014 Average
Acres Treated	CDPR	53,888	63,307	49,262	55,486
	Proprietary third party	56,500	35,963	63,441	51,968
Lb a.i. Applied	CDPR	97,249	113,749	88,325	99,774
	Proprietary third party	79,326	57,229	111,986	82,847

13.3 Target Pests

Mealybug, leafhopper, mites and leafroller were the top target insect pests in grapes. Mealybugs were targeted in 32.4% of the insecticide treated acres annually in 2012-2014, and cause significant losses in grapes as described in the following section. Chlorpyrifos was among the leading active ingredients used to control mealybugs in grapes.

Table 67. Top Insect Pests in Grapes – Pest Acres 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
LEAFHOPPER	214,055	335,066	505,288	351,470	14.7%
MEALYBUG, VINE	290,109	339,436	381,437	336,994	14.1%
MITE, 2-SPOTTED	306,840	412,218	245,865	321,641	13.4%
MEALYBUG	173,303	236,532	460,974	290,270	12.1%
MITE	93,420	194,780	352,143	213,448	8.9%
LEAFROLLER, OMNIVOROUS	185,777	190,013	197,493	191,094	8.0%
MITE, PACIFIC SPIDER	142,983	227,078	168,748	179,603	7.5%
MEALYBUG, GRAPE	154,013	99,764	190,499	148,092	6.2%
U.S. Total	**2,421,606**	**3,176,355**	**3,590,164**	**3,062,708**	**Column Total 84.9%**

Source: Proprietary third party data.

13.3.1 Mealybugs

According to the University of California Integrated Pest Management Program, three species of mealybug (*Pseudococcus*) can infest vineyards, including grape, obscure, and longtailed mealybugs. Grape and obscure mealybugs are the primary species of concern in North Coast and San Joaquin Valley vineyards, obscure and longtailed mealybugs cause damage in Central Coast vineyards, and longtailed mealy bug may occur in the Coachella Valley [2]. Mealybugs damage grapes by contaminating clusters with cottony egg sacs, larvae, adults, and honeydew. Often the honeydew is covered with a black sooty mold. All three species can transmit grape viruses.

A new species of mealybug, the vine mealybug, *Planoccoccus ficus*, became established a decade ago and has spread throughout all grape producing areas. This species produces several generations per year, feeds more and produces significantly more honeydew than the other three species, consequently causes significantly more economic damage to the crop than the other species, and can also transmit grape viruses [3].

Chlorpyrifos was the third leading insecticide active ingredient used in grapes to control mealybugs. Chlorpyrifos was used on 5.5% of the pest acres that targeted mealybug in 2012-2014. With an average cost of $15.51 per acre, chlorpyrifos costs 42% less than the average cost of all insecticide active ingredients used to control mealybug ($26.82).

Table 68. Leading Insecticide Active Ingredients Used to Control Mealybug in Grapes – Pest Acres 2012-2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
SPIROTETRAMAT	295,211	336,597	496,561	376,123	48.5%
IMIDACLOPRID	150,500	199,106	248,790	199,465	25.7%
CHLORPYRIFOS	48,183	30,419	48,465	42,356	5.5%
PETROLEUM OIL	28,398	28,673	58,372	38,481	5.0%
CLOTHIANIDIN	29,986	28,334	39,145	32,489	4.2%
BUPROFEZIN	23,549	15,433	46,900	28,627	3.7%
CYFLUTHRIN	11,171	21,873	35,324	22,790	2.9%
U.S. Total	**617,426**	**675,731**	**1,032,910**	**775,356**	**Column Total 95.5%**

Source: Proprietary third party data.

Chlorpyrifos is labeled for use on grapes east of the Continental Divide. However, chlorpyrifos was granted Special Local Needs labels [Section 24(c)] for control of grape and vine mealybug in California, and for control of grape mealybug and cutworm in Colorado, Idaho and Washington.

The majority of chlorpyrifos used in grapes is applied as a dormant spray just prior to bud break, and for post-harvest for control of mealybug. Both applications are typically applied at 2.0 lb a.i./A at 150-300 GPA and are often combined with lime-sulfur treatments. In addition to dormant and post harvest sprays for mealybug, chlorpyrifos is used as a directed spray to the soil in grapes at 1-2 lb a.i./A for control of ants. Since the ants tend mealybugs, effective mealybug suppression occurs as a result of controlling ant populations. Prior to the approval of dormant use of chlorpyrifos, the only management option for grape mealybug was directed ground sprays for suppression of ants.

The need for post harvest treatment of grapes has increased in recent years with the spread of vine mealybug in all grape growing regions of the state of California,. Chlorpyrifos is considered by the University of California to be a foundation product for an effective and reliable mealybug management strategy. Timing of application is critical. If applied too early efficacy is compromised; however, if applications go on post bud break, significant phytotoxicity can result. Post harvest applications of chlorpyrifos have been very effective, since new infestations are generally discovered during the harvest process, and a timely treatment is critical for curtailing the spread of the pest to new vineyards.

13.4 Benefits of Chlorpyrifos in Grape

- Effective control of the grape and vine mealybug which are among the most important insect pests in grapes, as well as many other economically important insect pests such as grape borer and ants.
- Chlorpyrifos was granted Special Local Needs labels [Section 24(c)] for control of grape and vine mealybug in California, and control of grape mealybug and cutworm in Colorado, Idaho and Washington.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.
- Cost effective.

13.5 Chlorpyrifos Formulations, Rates, and Applications

The formulations of chlorpyrifos listed for controlling insect pests in grapes include Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, both for use in areas east of the Continental Divide, excluding Mississippi.

Location: CA [24(c) registration, CA-080009 R368-106]

- Pests: grape and vine mealybug,
- Application Type: airblast sprayer at 150-300 GPA
- Application Method: ground
- Rate: 0.94-1.88 lb a.i./A, do not apply more than 1.88 lb a.i./A per year
- Number of Applications: maximum 2 per year
- Season of Application: post harvest (1) and dormant/delayed dormant (1), oil-applied delayed dormant application of chlorpyrifos are most effective

Table 69. Leading Chemical Treatments for Insect Control in Grapes.

Note: Information in the "Application, Use and Efficacy" section reflects opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, others	-Oil-applied delayed dormant application of chlorpyrifos is most effective for mealybug control. Also applied post harvest. -Group 1B MOA.
Buprofezin	Applaud	-Applied post bloom; supplemental to chlorpyrifos applications. -An insect growth regulator. -Group 16 MOA.
Clothianidin	Belay	-Soil-applied using chemigation, or subsurface shank or hill drench followed by irrigation; ineffective in heavier soils. -Foliar in-season application; supplemental

Active Ingredient	Brand Names	Application, Use, and Efficacy
		to chlorpyrifos dormant and post harvest applications. -Group 4A MOA.
Imidacloprid	Several	-Soil-applied, best when applied in a drip system, ineffective in heavier soils. -Foliar in-season application; supplemental to chlorpyrifos dormant and post harvest applications. -Group 4A MOA.
Spirotetramat	Movento	-Foliar in-season application; supplemental to chlorpyrifos dormant and post harvest applications. -Group 23 MOA.
Thiamethoxam	Platinum	-Soil-applied using chemigation, or subsurface shank or hill drench followed by irrigation; most effective neonicotinoid in heavy soils. -Group 4A MOA.

13.6 **Grower Perspectives**

In late 2007, the EPA asked for public comments on issues related to the agricultural use of chlorpyrifos. The following is a selection of excerpts from grower organizations who responded to the EPA's request for input by explaining why they considered chlorpyrifos essential for protecting their crops. Submissions to the docket are public information and have been posted by the EPA at www.regulations.gov, docket number EPA-HQ-OPP-2007-*1005*. Growers also commented during public comment periods in 2011 (EPA-HQ-OPP-2008-0850-0025) and 2015 (EPA-HQ-OPP-0850-0224).

"For California wine grapes, chlorpyrifos predominantly is used for managing the recently introduced vine mealybug, a significant problem in some regions and threat across the state. Approximately 39,000 wine grape acres were treated in 2005, as published by the California Department of Pesticide Regulation. Chlorpyrifos is one of the few registered products and most efficacious for controlling vine mealybug, particularly its spread to non-infested areas. When used, the material is carefully applied at delayed dormancy or post harvest for direct kill or to suppress ants that impede biological control of mealybugs.... It is important...to maintain all safe and effective uses of chlorpyrifos in California wine grapes, at least until other efficacious alternatives become available." – California Association of Wine Grape Growers

"Chlorpyrifos is needed for control of a wide variety of pests. In California there are 17 counties infested with vine mealybug and once established, vine mealybug is difficult to

eradicate. Black widow spider has become a serious issue due to quarantine requirements on U.S. table grape exports, and for stone fruit growers there are similar demands for zero tolerance of Oriental fruit moth on exports destined to Mexico. Chlorpyrifos continues to provide a significant benefit in managing these pests." – California Grape and Tree Fruit League

13.7 Crop Consultant Perspective

In preparing this report, growers and crop consultants were recently asked to share their thoughts on the benefits and use of chlorpyrifos for pest control.

"For wine grapes, I use Lorsban to control vine mealybug. We're limited to using Lorsban only during the dormant season. While there are other replacements out there, they are far more costly. For mealybug, you just can't afford not to use chlorpyrifos. I also grow lemons and there's really no other product available that has the broad spectrum control we need for citrus. I spray once with Lorsban for scale, leafhoppers, etc. If I didn't have Lorsban for citrus, I'd have to spray two to three times with two or three other products just to get the same control." – Bernie Borges, Vineyard Management, Monterey Pacific, Inc. Soledad, CA (April 2009)

"Chlorpyrifos knocks down citricola scale, a very hard to control scale in citrus that has no natural predators. It is effective on a wide range of pests including red scale, cutworms, and katydids. In granular form, Lorsban 15G offers excellent ant control. In the winter, we use a half gallon per acre of Lorsban for mealybug control in grapes." – Dennis McFarlin, Pest Control Advisor, Gar Tootelian, Inc., Reedley, CA (April 2009)

13.8 References

1. National Grape and Wine Initiative. *Economic Impact Study*. January 19, 2007. http://www.ngwi.org/index.php?page_id=226. Accessed December 22, 2015.
2. University of California, UC IPM Online. *How to Manage Pests, Grape/Mealybugs*. July 2015. http://www.ipm.ucdavis.edu/PMG/r302301811.html. Accessed December 22, 2015.
3. University of California, UC IPM Online. *How to Manage Pests, Grape/Vine Mealybug*. July 2015. http://www.ipm.ucdavis.edu/PMG/r302301911.html. Accessed December 22, 2015.

14. Legume Vegetables (dry and succulent beans and peas)

14.1 Overview

Legume vegetables include dry beans and peas, and green or succulent beans and peas. Soybeans are excluded from this group and are addressed in a separate "Soybean" section in this document. An average of 2,637,396 acres of dry beans and peas were planted annually in the U.S. in 2012-2014. Over 75% of the dry bean and pea acres were grown in four Western states; North Dakota, Montana, Washington and Idaho.

Table 70. U.S. Dry Bean and Pea Production – Acres Planted 2012-2014.

State	Acres Planted			
	2012	2013	2014	2012-2014 Average
NORTH DAKOTA	1,159,987	933,999	910,000	1,00,1328
MONTANA	490,501	569,203	560,000	539,901
WASHINGTON	274,999	254,998	220,000	249,999
MICHIGAN	199,999	180,000	210,000	196,667
IDAHO	210,001	194,002	180,000	194,667
MINNESOTA	160,000	145,001	145,000	150,000
NEBRASKA	145,000	129,999	130,000	135,000
OTHER STATES	185,499	154,002	170,000	169,833
U.S. Total	**2,825,985**	**2,561,204**	**2,525,000**	**2,637,396**

Source: Proprietary third party data.

The dry bean and pea acreage was approximately six times larger than the combined acreage of green beans and peas. An average of 237,765 acres of green beans and 182,930 acres of green peas were grown annually in the U.S. in 2012-2014. The Midwest is the primary production area for both green beans and peas. Approximately 44% of the green beans acres were grown in the Midwest, 29% in the South, 17% in the Northeast, and 9% in the West. Approximately 63% of the green pea acres were grown in the Midwest, 32% in the West and 5% in the Northeast.

Table 71. U.S. Green (Succulent) Bean Production – Acres Planted 2012-2014.

State	Acres Planted			
	2012	2013	2014	2012-2014 Average
WISCONSIN	74,000	74,000	66,000	71,333
FLORIDA	46,781	46,781	34,997	42,853
NEW YORK	25,100	25,100	30,810	27,003
MICHIGAN	20,800	20,800	15,496	19,032
PENNSYLVANIA	15,200	15,200	11,600	14,000
GEORGIA	13,078	13,078	11,979	12,712
OREGON	13,500	13,500	8,500	11,833
OTHER STATES	41,777	38,380	36,839	38,999
U.S. Total	**250,236**	**246,839**	**216,221**	**237,765**

Source: Proprietary third party data.

Table 72. U.S. Green (Succulent) Pea Production – Acres Planted 2012-2014.

State	Acres Planted			
	2012	2013	2014	2012-2014 Average
MINNESOTA	80,200	80,200	68,600	76,333
WASHINGTON	41,800	41,800	40,800	41,467
WISCONSIN	39,500	39,500	37,700	38,900
OREGON	15,500	15,500	19,600	16,867
NEW YORK	9,822	9,822	8,445	9,363
U.S. Total	**186,822**	**186,822**	**175,145**	**182,930**

Source: Proprietary third party data.

14.2 Chlorpyrifos Use

Chlorpyrifos use in legume vegetables averaged only 1.6%, 0.6% and 0.2% of all active ingredient acres treated in dry beans and peas, green beans and green peas, respectively, in 2012-2014. Growers used an average of 10,127 lb a.i. of chlorpyrifos annually to control insect pests in legume vegetables in 2012-2014, a 60% increase from average annual use in 2003-2007 (6,329 lb a.i.). Chlorpyrifos was primarily used as a soil applied preplant incorporated, or at-plant T-band application for control of seed corn maggot.

Table 73. Chlorpyrifos Use in Legume Vegetables – Acres Treated and Lb. a.i. Applied 2012-2014.

Crop	Data	2012	2013	2014	2012-2014 Average
Dry Beans and Peas	Acres Treated	14,446	19,032	1,356	11,611
	Lbs a.i. Applied	9,568	8,289	848	6,235
Green Beans	Acres Treated	5,575	4,946	2,250	4,257
	Lbs a.i. Applied	3,929	4,788	2,112	3,610
Green Peas	Acres Treated	642	--	260	301
	Lbs a.i. Applied	602	--	244	282
Total US	**Acres Treated**	**20,663**	**23,978**	**3,866**	**16,169**
	Lbs a.i. Applied	**14,099**	**13,077**	**3,204**	**10,127**

Source: Proprietary third party data.

14.3 Target Pests

The seed corn maggot is a perennial pest of the seeds and seedlings of beans, peas and a variety of other crops. Seed corn maggots can decimate a crop stand if left untreated. Seed corn maggot larvae feed on the cotyledons and the below-ground hypocotyls tissue of seedlings, resulting in a variety of damage symptoms. Feeding damage can injure or kill crop seedlings before they emerge. Poor, uneven crop emergence is a symptom of seed corn maggot damage. The available chemical control options are preventive; no insecticide is labeled for use once outbreak has occurred. Growers can apply a broadcast soil incorporated insecticide treatment prior to planting, or apply the soil insecticide in band over the crop row at-planting. Another option is to plant seed pretreated with an insecticide seed treatment [1] [2] [3].

Chlorpyrifos broadcast applied prior to planting and incorporated into the soil or applied in a T-band over the row at planting provides effective control of seed corn maggot. Maintaining the availability of chlorpyrifos in the legume vegetable insecticide complex is important for the control of this insect pest, and the viability of long-term resistance management programs.

14.4 Benefits of Chlorpyrifos in Legume Vegetables

- Effective control of seed corn maggot.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.
- Cost effective.

14.5 Chlorpyrifos Formulations, Rates, and Applications

The formulations listed for controlling insect pests in legume vegetables include Lorsban-4E (and other 4 lbs per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, and Lorsban 50W.

Location: FL, ID, MI, MN, MT, ND, NY, OR, PN, WA, WI

- Product: Lorsban-4E, Lorsban Advanced, and Lorsban 75WG and Lorsban 50W
- Pests: seed corn maggot
- Application Type: broadcast preplant incorporated or at-plant T-band application
- Application Method: ground
- Rate: 1.0 lb a.i./A preplant broadcast incorporated or 1.8 fl. oz. of Lorsban-4E per 1000 feet of row at-plant T-band application
- Number of Applications: 1
- Season of Application: preplant or while planting

Table 74. Leading Chemical Treatments for Insect Control in Legume Vegetables.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, Lorsban 50W, others	-Controls seed corn maggot. -Group 1B MOA for resistance management. -Cost effective.
Bifenthrin	Capture	-Controls corn root maggot, corn rootworm, wireworm and grubs. -Broad spectrum. -Group 3A MOA.

Source: [3].

14.6 Non-Chemical Alternatives

The adult seed corn maggot is attracted to rotting organic matter and freshly plowed fields. Susceptible crops should not be planted in fields where animal or green manure has recently been applied. Spring plowing of animal manure, weeds, green manure, or cover crops should be avoided. Cultural practices that hasten emergence, such as delayed seeding and shallow planting, reduce seed corn maggot damage potential.

14.7 References

1. University of Wisconsin Extension. *See Corn Maggot. A3820.* January 2, 2007. http://corn.agronomy.wisc.edu/Management/pdfs/A3820.pdf. Accessed December 31, 2015.
2. University of Minnesota. Department of Entomology. *Pest Profiles/Seed Corn Maggot.* https://www.vegedge.umn.edu/pest-profiles/pests/seed-corn-maggot. Accessed December 31, 2015.

3. University of Illinois Extension. Purdue Extension, K-State Research and Extension, University of Minnesota Extension, University of Missouri Extension. *Midwest Vegetable Production Guide for Commercial Growers 2016*. December 2015. https://ag.purdue.edu/btny/midwest-vegetable-guide/Pages/default.aspx. Accessed December 31, 2015.

15. Mint

15.1 Overview

An average of 92,000 acres of mint was harvested annually in the U.S. in 2012-2014. Approximately 79% was grown in the Pacific Northwest (Washington, Idaho, Oregon) These three states plus Indiana grow 91% of the U.S. mint acreage. Approximately 75% of the mint grown is peppermint and the rest is spearmint (USDA, NASS).

Table 75.U.S. Mint Production – Acres Harvested 2012-2014.

State	Acres Harvested (000)			
	2012	2013	2014	2012-2014 Average
WASHINGTON	27.8	33.0	30.0	30.3
OREGON	27.1	23.8	22.5	24.5
IDAHO	17.3	16.5	15.9	16.6
INDIANA	13.2	12.1	12.2	12.5
OTHER STATES	10.3	7.6	6.9	8.3
U.S. Total	**95.7**	**93.0**	**87.5**	**92.1**

Source: USDA, NASS.

15.2 Chlorpyrifos Use

No information was available on the number of treated acres or lb a.i. of chlorpyrifos applied on mint. University insect management guides recommend chlorpyrifos to control several economically important insect pests including armyworm, cutworm, mint root borer, garden symphylan and cranefly in mint.

15.3 Target Pests

New mint fields are planted with rootstock or underground runners from existing plants. Mint is planted as a row crop, but by the second year the plants spread out creating a solid mint field. Mint is grown in a field for 3 to 5 years and then rotated with another field crop before it is replanted to mint [1].

Several insect pests can damage mint including aphids, borers, loopers, mites, thrips, wireworms, worms and weevils. Several insecticides including chlorpyrifos, acephate, chlorantraniliprole, methomyl, thiamethoxam, indoxacarb, methoxyfenozide, spinosad, spinetoram, tebufenozide, and others are registered to control insect pests in mint. Chlorpyrifos provides broad spectrum control of a number of insect pests in mint including armyworm, cutworm, redbacked cutworm, garden symphylan, root borer and cranefly [2]. Each causes significant losses as described in the following sections.

15.3.1 Armyworms and Cutworms

Several species of armyworms and cutworms such as Bertha armyworm, redbacked cutworm, mint cutworm, spotted cutworm, and variegated cutworm feed on mint leaves, reduce oil yield and sometimes cause death of mint plants [2]. Armyworms and cutworms can cause yield losses of up to 80% [1]. Redbacked cutworm is a key pest of mint east of the Cascades. As mint begins to send up aerial growth in the spring, larvae feed underground by day, clipping off new spring shoots at or below ground level. At night, larvae feed on and above the soil surface. In some years, damage to mint during May and early June in central Oregon has been severe enough to result in extensive stand loss in absence of larval control. Chlorpyrifos is one of several insecticides recommended for control of armyworms and cutworms in mint.

15.3.2 Mint Root Borer

The mint root borer is widespread and one of the most serious pests of peppermint in the Pacific Northwest [1]. Larvae feed inside mint rhizomes and on mint roots resulting in reduced vigor, winterkill, reduced regrowth in spring, declining yields, and shortened stand life. Using new certified or quarantined planting materials has helped minimize infestations of mint root borer. This pest has not been present in the Midwest, in part, due to quarantine practices and requirements that growers use only certified planting material. However, there have been some reports of mint root borer in the Midwest.

CropLife Foundation notes that approximately 30% of the mint acres in the Pacific Northwest are treated to control mint root borers [1] . Chlorpyrifos is one of only a few chemical treatments registered for mint root borer which include chlorpyrifos, chlorantraniliprole, chlorantraniliprole + thiamethoxam, and ethoprop [2]. Parasitic nematodes are also recommended for control of this insect pest.

15.3.3 Garden Symphylan

The garden symphylan feeds on mint hairs, root tissue and underground stems. Heavy feeding causes plant stunting, poor stem elongation, and small, chlorotic leaves. This insect is a very serious pest of many crops in western Oregon. Chlorpyrifos is one of four active ingredients listed for control of symphylan, which include chlorpyrifos, ethoprop, metam sodium and 1,3-dichloropropene. Chlorpyrifos has the best toxicological profile of the four and is easy to use compared to metam sodium (a soil fumigant with long pre-plant interval) and 1,3-dichloropropene. The CropLife Foundation estimates that 69% of mint acres in western Oregon are treated for symphylans [1].

15.3.4 Cranefly

Cranefly larvae, called leatherjackets, feed on roots and underground rhizomes of mint plants from the fall through spring months. Cranefly control is a unique benefit of chlorpyrifos. No insecticides are labeled for cranefly control, however, research and field use in Oregon indicate chlorpyrifos is effective against craneflies. Chlorpyrifos is not labeled for cranefly control in mint, but may be used because it is registered to control other pests on the crop [2].

15.4 Benefits of Chlorpyrifos in Mint

- Effective control of several primary insect pests in mint including armyworms, cutworms, mint root borer, and garden symphylans as well as other economically important insect pests such as craneflies.
- Active on foliar-feeding and soil-dwelling insect pests.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.
- Lower mammalian toxicity compared to some other soil applied insecticides used in mint – ethoprop, metam sodium, 1,3-dichloropeopene.
- Easier to use for garden symphylan control compared to the soil fumigants metam sodium and 1,3-dichloropropene.

15.5 Chlorpyrifos Formulations, Rates, and Applications

The formulations of chlorpyrifos listed for controlling insect pests in mint include Lorsban-4E (and other 4 lbs per gallon EC formulations of chlorpyrifos) and Lorsban Advanced.

Location: ID, IN, OR, WA

- Pests: armyworm and cutworm including redbacked cutworm
- Application Method: ground or chemigation
- Rate: 1.0 lb – 2.0 lb a.i./A (1 lb a.i./A when larvae are less than 0.75 inch long; 2 lb a.i./A larvae are longer than 0.75 inch)
- Number of Applications: 1 per growing season
- Season of Application: May or June when damaging insect populations are developing or present

Location: ID, IN, OR, WA

- Pests: mint root borer
- Application Method: chemigation or by ground immediately followed by 1 inch of sprinkler irrigation
- Rate: 2.0 lb a.i./A
- Number of Applications: 1
- Season of Application: post-harvest (August – early September)

Location: ID, IN, OR, WA

- Pests: garden symphylan
- Application Method: broadcast preplant incorporated
- Rate: 2.0 lb a.i./A
- Number of Applications: 1
- Season of Application: preplant

15.6 Non-Chemical Alternatives

Crop rotation, quarantine practices, the use of certified planting material, and fall tillage are used to control insect pests in mint. A number of organic and natural insect control products such as *Buckholderia* spp., *Chromobacterium subtsugae*, *Beauveria bassiana*, parasitic nematodes, and neem oil or azadirachtin are registered for the control of insect pests in mint.

15.7 References

1. Gianessi L. *The Benefits of Insecticide Use: Mint*. CropLife Foundation. March 2009. https://croplifefoundation.files.wordpress.com/2012/07/combined_document_mint.pdf. Accessed December 24, 2015.
2. 2016 Pacific Northwest Insect Management Handbook. http://insect.pnwhandbooks.org/agronomic/mint. Accessed December 20, 2015.

16. Pineapple (nonbearing only)

16.1 Overview

Hawaii ranks first in national production of pineapple and, excluding the territory of Puerto Rico, produces 100% of the commercially grown pineapple in the U.S. Approximately 13,900 acres of pineapple were produced in Hawaii 2006, the last year data was available from the NASS before the pineapple program was discontinued.

16.2 Chlorpyrifos Use

A 24(c) Special Local Need label allows the use of chlorpyrifos (Lorsban Advanced) to control mealybug on nonbearing pineapple in Hawaii (24c SLN: HI-090001 [expires 9/30/19]). No information was available on the number of treated acres or lb a.i. of chlorpyrifos applied for this use.

16.3 Target Pests

Pineapple has relatively few insect pests. Scales, symphylids, thrips (which vector the Yellow Spot Virus) and mites are seldom serious problems. Mealybugs and the ants which tend them, however, are associated with the very serious mealybug wilt disease. Mealybug wilt can occur if mealybug populations become high. Entire fields, up to 50% of the plants in a field, can be lost if control is not undertaken. Most often the ants are controlled which allow natural predators to keep the mealybug population in check [1]. Chlorpyrifos provides controls of mealybug which reduces transmission of mealybug wilt disease to pineapple.

16.4 Benefits of Chlorpyrifos in Pineapple

- Chlorpyrifos is the only insecticide labeled for mealybug control on the pineapple crop.
- Effective control of mealybug which reduces transmission of mealybug wilt disease to pineapple.

16.5 Chlorpyrifos Formulations, Rates, and Applications

The formulation listed for control of mealybug on pineapple ling in Hawaii is Lorsban Advanced.

Location: HI

- Pests: mealybug
- Application Type: foliar
- Application Method: ground
- Rate: 0.94 lb a.i./A
- Number of Applications: 3

- Season of Application: apply during establishment year (plant crop) of permanent pineapple plantings. Apply to foliage post-plant and repeat at 30-day intervals for up to 3 months after planting.

16.6 References

1. Regional IPM Centers. *Crop Profile for Pineapples in Hawaii*. January 2000. http://www.ipmcenters.org/cropprofiles/docs/HIpineapples.pdf. Accessed December 30, 2015.

17. Onion (dry bulb)

17.1 Overview

An average of over 137,000 acres of onions was grown annually in the U.S. in 2012-2014. Onions were grown in more than 20 states; the top producing states were California, Washington, Oregon, Georgia, and Texas.

Table 76. US Onion Production – Acres Planted 2012-2014.

State	Acres Planted			
	2012	2013	2014	2012-2014 Average
CALIFORNIA	45,200	45,200	45,500	45,300
WASHINGTON	26,600	26,600	22,000	25,067
OREGON	19,400	19,400	19,700	19,500
GEORGIA	12,700	12,700	12,000	12,467
TEXAS	10,100	10,100	14,952	11,717
NEW YORK	10,200	10,200	8,200	9,533
IDAHO	8,700	8,700	7,000	8,133
COLORADO	6,500	6,500	4,100	5,700
U.S. Total	**139,400**	**139,400**	**133,452**	**137,417**

Source: Proprietary third party data.

17.2 Chlorpyrifos Use

Chlorpyrifos was the fifth most-used active ingredient for control of insect pests in onions, and was used on an average of 7.8% of the total active ingredient treated acres in 2012-2014.

Table 77. Leading Insecticide Active Ingredients Used in Onions – Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
METHOMYL	220,917	212,783	154,865	196,188	25.6%
SPIROTETRAMAT	103,133	116,977	94,167	104,759	13.7%
SPINETORAM	91,901	85,568	108,319	95,263	12.4%
OXAMYL	77,729	72,271	53,314	67,771	8.8%
CHLORPYRIFOS	57,667	72,761	48,320	59,583	7.8%
CYHALOTHRIN-LAMBDA	52,685	68,196	50,986	57,289	7.5%
U.S. Total	**784,606**	**803,197**	**713,405**	**767,069**	**Column Total 75.7%**

Source: Proprietary third party data.

Growers used an average of 54,850 lb a.i. of chlorpyrifos annually to control insect pests in onions in 2012-2014, a decrease of 20% in average annual use from 2003-2007 (68,805 lb a.i.).

Table 78. Chlorpyrifos Use in Onions – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos Use	2012	2013	2014	2012-2014 Average
Acres Treated	57,667	72,761	48,320	59,583
Lb a.i. Applied	56,413	64,610	43,526	54,850

17.3 Target Pests

Maggots (onion maggot, root maggot, corn seed maggot, and bean seed maggot) are important pests of onions. Larvae of seed corn maggots attack germinating seedlings, feeding on the developing roots and epicotyl. Their damage is usually restricted to the very early seedling stage. Onion maggots inflict similar damage, but can continue to feed on the expanding bulb during later stages of growth. This results in increased rot in bulbs held in storage [1]. Severe infestations can cause losses as high as 70-100%.

Table 79. Top Insect Pests in Onions – Pest Acres 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
THRIP	364,090	425,969	386,126	392,062	50.3%
THRIP, ONION	279,907	230,274	142,730	217,637	18.6%
MAGGOT, SEED, ROOT, ONION	79,935	76,044	99,577	85,185	12.9%
THRIP, WESTERN FLOWER	103,592	107,201	87,331	99,375	11.4%
NEMATODE	25,369	33,946	38,694	32,670	5.0%
U.S. Total	**973,389**	**996,782**	**890,889**	**953,687**	**Column Total 98.3%**

Source: Proprietary third party data.

Chlorpyrifos applied as an in-furrow treatment is the leading insecticide used to control root maggots in onion. Chlorpyrifos is one of only three treatment options for root maggots (onion, seedcorn root maggot) along with cyromazine, thiamethoxam and clothianidin + imidacloprid seed treatments. Chlorpyrifos is the only non-seed treatment option available in dry bulb onion production. Foliar applications of pyrethroids and other inexpensive broad spectrum insecticides are used for adult control.

Table 80. Leading Insecticide Active Ingredients Used to Control Maggots in Onions – Pest Acres 2012-2014.

Insecticide	Pest Acres				% of Total Pest Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CHLORPYRIFOS	51,088	59,956	45,782	52,275	62.1%
ZETA-CYPERMETHRIN	--	1,753	13,897	5,217	6.2%
BIFENTHRIN	2,467	--	13,098	5,188	6.2%
CYHALOTHRIN-LAMBDA	4,470	4,950	4,212	4,544	5.4%
CYPERMETHRIN	--	--	13,098	4,366	5.2%
U.S. Total	**77,180**	**76,044**	**99,225**	**84,150**	**Column Total 85.1%**

Source: Proprietary third party data.

17.4 <u>Benefits of Chlorpyrifos in Onions</u>

- Chlorpyrifos is the leading soil-applied insecticide for root maggot control in dry bulb onion.

- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance with Group 4A and Group 17 seed treatments.
- Cost effective.

17.5 Chlorpyrifos Formulations, Rates, and Applications

Current chlorpyrifos formulations listed for controlling insect pests in onions include Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG and Lorsban 15G (and other chlorpyrifos granular formulations).

Location: CA, CO, GA, OR, MI, NY, WA

- Pests: onion maggot
- Application Type: ground/at plant or post-plant soil drench
- Application Method: banded (2-4 inch) over the row
- Rate: 1.0 lb a.i./A
- Number of Applications: 1
- Season of Application: spring, at plant or early post-plant

Table 81. Leading Chemical Treatments for Insect Control in Onion.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban 4E, Lorsban 75WG, Lorsban 15G, others	-Highly effective on root maggot. -The only non-seed treatment option available. -Group 1B MOA for resistance management. -Cost effective.
Clothianidin + Imidacloprid	Sepresto	-Seed treatment. - Group 4A MOA.
Cyromazine	Trigard	-Seed treatment. - Group 17 MOA.
Thiamethoxam	FarMore F1500	-Seed treatment. -Group 4A MOA.

17.6 References

1. University of California, UC IPM Online. How to Manage Pests, Onion and Garlic/Maggots. June 2008. http://www.ipm.ucdavis.edu/PMG/r584300211.html. Accessed December 15, 2015.

18. Peanuts

18.1 Overview

An average of over 1.25 million acres of peanuts was grown annually in the U.S. in 2012-2014. Georgia, Alabama, Florida and Texas account for 82% of planted peanut acres. Other peanut producing states include North and South Carolina, Virginia, and Oklahoma.

Table 82. U.S. Peanut Production – Acres Planted 2012-2014.

State	Acres Planted			
	2012	2013	2014	2012-2014 Average
GEORGIA	699,999	429,996	595,000	574,998
ALABAMA	186,003	140,000	175,000	167,001
FLORIDA	179,999	135,001	170,000	161,667
TEXAS	125,000	117,002	125,000	122,334
SOUTH CAROLINA	90,001	81,000	111,001	94,001
NORTH CAROLINA	104,000	81,000	93,999	93,000
OKLAHOMA	26,000	18,000	17,000	20,333
VIRGINIA	20,000	16,000	19,000	18,333
U.S. Total	**1,431,003**	**1,018,000**	**1,306,000**	**1,251,668**

Source: Proprietary third party data.

18.2 Chlorpyrifos Use

Chlorpyrifos was the sixth most-used active ingredient for control of insect pests in peanuts and was used on an average of 5.5% of the total active ingredient treated acres in 2012-2014.

Table 83. Leading Insecticide Active Ingredients Used in Peanuts – Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
PHORATE	733,568	415,270	423,141	523,993	24.5%
DIFLUBENZURON	312,548	248,067	525,833	362,149	16.9%
BIFENTHRIN	335,194	243,112	254,597	277,634	13.0%
CYHALOTHRIN-LAMBDA	310,789	97,956	171,996	193,581	9.0%
ACEPHATE	157,858	120,218	149,369	142,482	6.7%
CHLORPYRIFOS	131,395	94,758	124,853	117,002	5.5%
METHOXYFENOZIDE	65,024	96,359	86,046	82,476	3.8%
U.S. Total	**2,514,997**	**1,671,812**	**2,240,934**	**2,142,581**	**Column Total 79.3%**

Source: Proprietary third party data.

Growers used an average of 211,589 lb a.i. of chlorpyrifos annually to control insect pests in peanuts in 2012-2014, a 77% increase in average annual use from 2003-2007 (119,213 lb a.i.). The increased use of chlorpyrifos in peanuts first occurred in 2008 when growers used 255,142 lb a.i. of chlorpyrifos on 160,785 peanut acres, more than doubling the 111,844 lb a.i. applied in 2007.

Table 84. Chlorpyrifos Use in Peanuts – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	131,395	94,758	124,853	117,002
Lb a.i. Applied	229,658	180,420	224,687	211,589

Source: Proprietary third party data.

18.3 <u>Target Pests</u>

While thrips, armyworm, threecornered alfalfa hoppers, and corn earworm are the top target pests in peanuts; secondary insect pests like southern corn rootworm, lesser cornstock borer, wireworm, and cutworms can damage thousands of acres of peanuts. Chlorpyrifos was used to control this secondary group of economically important insect pests, and is the only insecticide recommended by universities for corn rootworm, lesser cornstalk borer and wireworm control in peanuts in 2015 [1] [2].

18.3.1 Corn Rootworm

The southern corn rootworm is one of the most troublesome pests in peanut production. The southern corn rootworm is the larvae of the spotted cucumber beetle, but the beetles do not damage peanuts. The larvae feed on roots, pegs, and pods below the ground surface. Often the only signs of a rootworm infestation are the tiny holes they leave in the pods after feeding. Chlorpyrifos is used on 78.8% of the active ingredient acres treated for corn rootworm and is the leading active ingredient used to control this pest.

Table 85. Leading Insecticide Active Ingredients Used to Control Corn Rootworm in Peanuts – Pest Acres 2012-2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CHLORPYRIFOS	72,899	82,423	53,009	69443	78.8%
PHORATE	16,067	2,280	21,964	13437	15.3%
METHOXYFENOZIDE	9,272	--	--	3091	3.5%
DIFLUBENZURON	--	--	4,519	1506	1.7%
CYHALOTHRIN-LAMBDA	--	1,835	--	612	0.7%
U.S. Total	**98,239**	**86,538**	**79,491**	**88089**	**100.0%**

Source: Proprietary third party data.

18.3.2 Lesser Cornstalk Borer

The lesser cornstalk borer is also destructive to peanut production. Larvae attack the peanut stem at or just below the crown, and also tunnel into lateral branches, pegs and pods. Stem damage to the water-conducting xylem tissue on small plants can exacerbate drought stress throughout the growing season. Direct injury to pegs and pods may be so severe as to cause complete crop destruction under outbreak conditions.

Diflubenzuron and chlorpyrifos were the leading active ingredients used for control of lesser cornstalk borer in peanuts nationwide, while chlorpyrifos was the leading active ingredient used in Georgia, the highest peanut acreage state. Chlorpyrifos was the leading soil applied insecticide which provides direct control of lesser cornstalk borer larvae. Diflubenzuron is a foliar applied insecticide used to control adults and not the larvae.

Table 86. Leading Insecticide Active Ingredients Used to Control Lesser Cornstock Borer in Peanuts – Pest Acres 2012-2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
DIFLUBENZURON	1,315	1,626	115,558	39,500	75.4%
CHLORPYRIFOS	14,344	--	12,817	9,054	17.3%
FLUBENDIAMIDE	--	--	9,030	3,010	5.7%
PHORATE	--	1,262	1,129	797	1.5%
U.S. Total	**15,659**	**2,888**	**138,535**	**52,361**	**100.0%**

Source: Proprietary third party data.

18.3.3 Aflatoxin and White Mold

White mold is a common and often destructive soil-borne disease in peanut fields, and has become more prevalent and more severe. Lesser cornstalk borer damage triggers aflatoxin contamination and southern stem rot "white mold" infection by giving the causative fungi access to the peanut plant at larval feeding sites. Aflatoxins are highly toxic chemicals produced by certain mold fungi, and are harmful or fatal to livestock as well as considered carcinogenic to animals and humans. Chlorpyrifos has been widely used to inhibit the growth and development of white mold by protecting the peanut crown, lateral branches, roots, pegs, and pods from insect injury. Based on results from a study published in 2006 to examine the impact of adding Lorsban 15G to reduce fungicide rates, Dr. Tim Brenneman, University of Georgia Extension plant pathologist, noted that,

"…Lorsban 15G is a good multi-purpose tool and good supplement for a white mold control program" [3].

18.4 Benefits of Chlorpyrifos in Peanuts

- The insecticide most used to control corn rootworm and lesser cornstalk borer.
- Effective control of the primary insect pests in peanuts including corn rootworm, lesser cornstock borer and cutworms.
- Protects against aflatoxin contamination and white mold infection by reducing insect injury.
- Provides broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.
- Cost effective.

18.5 Chlorpyrifos Formulations, Rates, and Applications

The formulation for chlorpyrifos for controlling insects in peanuts is 15G (and other chlorpyrifos granular formulations).

Location: AL, GA, FL, SC, NC, VA, TX, OK, MS, LA

- Pests: lesser cornstalk borer, southern corn rootworm, cutworm,
- Application Type: at plant or post-plant
- Application Method: ground granular applicator
- Rate: 2.0 lb a.i./A
- Number of Applications: 1
- Season of Application: June – August

18.6 Grower/Researchers

In late 2007, the EPA asked for public comments on issues related to the agricultural use of chlorpyrifos. Following is a selection of excerpts from a grower organization and a university specialist, who responded to the EPA's request for input by explaining why they considered chlorpyrifos essential for protecting their crops. Submissions to the docket are public information and have been posted by the EPA at www.regulations.gov, docket number EPA-HQ-OPP-2007-1005. Growers also commented during public comment periods in 2011 (EPA-HQ-OPP-2008-0850-0025) and 2015 (EPA-HQ-OPP-0850-0224).

"Chlorpyrifos is the only active ingredient labeled to protect peanut crops from lesser corn stalk borers, southern corn rootworm, burrower bugs, and wireworms. There is great potential to have problems with any or all of these insects in peanut farming regions. With no replacement chemistry available, the loss of chlorpyrifos would eliminate the only option for control of these destructive insects. The potential of economic loss to farmers caused by these insects could virtually eliminate peanut production in many regions." – Western Peanut Growers Association

"Lorsban 15G is a cost-effective option that provides protection against the lesser cornstalk borer and Southern corn rootworm, as well as suppression of white mold." – Tim Brenneman, University of Georgia Extension Plant Pathologist

18.7 References

1. Clemson University. *South Carolina Pest Management Handbook for Field Crops. 2015. Peanut Insect Management.* 2015. http://www.clemson.edu/extension/rowcrops/pest/files/2015pestmanagementfiles.pdf/peanutinsectcontrolPMH2015.pdf. Accessed January 2, 2016.
2. University of Georgia Extension. *UGA Extension Special Bulletin 28. Crop Pest Management Handbook – 2015. Peanut Insect Control.* 2015. http://www.ent.uga.edu/pest-management/Commercial-Peanut.pdf. Accessed January 2, 2016.

3. Huber, A. and Bader Rutter and Associates. *Revisiting A Product, Lorsban 15G was studied for cost-saving potential with white mold control.* The Peanut Grower, June 2006. pg. 19.

19. Pome and Stone Fruit

U.S. stone fruit crops include cherries, peaches, nectarines, plums, and prunes. Pome fruit crops include apples and pears.

19.1 Cherries

The U.S. is the world's second largest cherry producing country. Michigan, Washington and California are the largest cherry producing states; other states include Oregon, Utah, New York and Wisconsin. An average of 142,107 acres of cherries was grown in the U.S. in 2012-2014. Michigan produces approximately 75% of the tart cherry crop, and Washington and Oregon account for about 70% of the sweet cherries produced.

Table 87. U.S. Cherry Production – Acres Grown 2012-2014.

State	Acres Grown			
	2012	2013	2014	2012-2014 Average
MICHIGAN	47,658	47,658	43,925	46,414
WASHINGTON	41,781	41,781	41,049	41,537
CALIFORNIA	36,308	36,308	38,205	36,940
OREGON	18,109	18,109	15,430	17,216
Total U.S.	**143,856**	**143,856**	**138,609**	**142,107**

Source: Proprietary third party data.

19.1.1 Chlorpyrifos Use

Chlorpyrifos was among the top eight most-used insecticides for controlling insect pests in cherries, and was used on an average of 5.5% of the active ingredient treated acres in 2012-2014.

Table 88. Leading Insecticide Active Ingredients Used in Cherries – Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
SPINOSYN	161,158	108,384	94,840	121,461	13.9%
IMIDACLOPRID	83,568	104,216	132,079	106,621	12.2%
PETROLEUM OIL	72,499	79,961	92,224	81,561	9.4%
PHOSMET	47,532	73,268	42,981	54,594	6.3%
CYHALOTHRIN-LAMBDA	29,752	60,921	61,303	50,659	5.8%
MALATHION	75,906	23,635	45,451	48,331	5.5%
SPINETORAM	25,164	62,471	56,838	48,158	5.5%
CHLORPYRIFOS	42,133	43,304	59,032	48,156	5.5%
THIAMETHOXAM	27,351	43,224	52,373	40,983	4.7%
U.S. Total	**822,179**	**892,317**	**899,837**	**871,444**	**Column Total 68.9%**

Source: Proprietary third party data.

Growers used an average of 76,960 lb a.i. of chlorpyrifos annually to control insect pests in cherries in 2012-2014, nearly equal to the average annual use in 2003-2007 (80,140 lb a.i.). An average of 32,833 lb a.i. (42.7%) was used annually in Washington state, and an average of 21,743 lb a.i. (28.3%) was used in Michigan in 2012-2014.

Table 89. Chlorpyrifos Use in Cherries – Lb. a.i. Applied 2012-2014.

State	Lb. a.i. Applied				% of Total a.i. Applied (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
WASHINGTON	31,790	31,628	35,080	32,833	42.7%
MICHIGAN	15,091	14,596	35,542	21,743	28.3%
CALIFORNIA	987	4,083	2,610	2,560	3.3%
OTHER STATES	17,525	21,759	20,189	19,824	25.8%
Total US	**65,394**	**72,066**	**93,421**	**76,960**	**100.0%**

Source: Proprietary third party data.

19.1.2 Target Pests

Some of the most troublesome insect pests in cherries are fruit flies, plum curculio, leafrollers, and mites.

Table 90. Top Insect Pests in Cherries – Pest Acres 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
FLY, CHERRY FRUIT	227,550	241,865	199,064	222,826	25.6%
SPOTTED WING DROSOPHILA	120,103	141,343	194,121	151,856	17.4%
CURCULIO, PLUM	77,314	124,789	148,787	116,963	13.4%
FLY, FRUIT	70,848	92,663	67,604	77,038	8.8%
LEAFROLLER	55,016	78,552	56,056	63,208	7.3%
MITE, 2-SPOTTED	36,522	50,276	61,958	49,586	5.7%
LEAFROLLER, OBLIQUEBANDED	31,906	73,966	39,652	48,508	5.6%
U.S. Total	**1,013,019**	**1,221,031**	**1,240,175**	**115,8075**	**Column Total 83.8%**

Source: Proprietary third party data.

Michigan and Washington each have unique insect pest problems to manage. The primary insect pests in Michigan cherries include plum curculio, fruit flies, green fruitworm, and leafrollers.

Table 91. Top Insect Pests in Michigan Cherries – Pest Acres 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CURCULIO, PLUM	77,314	124,789	148,182	116,762	51.2%
FLY, CHERRY FRUIT	61,053	68,897	70,216	66,722	29.3%
FRUITWORM, GREEN	26,856	38,521	53,503	39,627	17.4%
FLY, FRUIT	14,581	20,046	18,092	17,573	7.7%
SPOTTED WING DROSOPHILA	--	3,068	41,471	14,846	6.5%
LEAFROLLER	3,445	10,294	21,847	11,862	5.2%
U.S. Total	**214,800**	**301,614**	**410,318**	**308,911**	**Column Total 117.2%**

Source: Proprietary third party data.

Michigan cherry growers primarily used chlorpyrifos to control plum curculio, green fruitworm and leafrollers. In addition, Michigan cherry growers rely on chlorpyrifos for American plum borer and peachtree borer control. Borers can seriously impact cherry production if not controlled.

Table 92. Leading Insecticide Active Ingredients Used in Michigan Cherries – Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
PHOSMET	46,628	70,364	41,721	52,904	23.2%
THIAMETHOXAM	24,953	34,707	45,314	34,991	15.3%
IMIDACLOPRID	5,385	19,511	54,860	26,585	11.7%
ZETA-CYPERMETHRIN	19,464	23,643	19,739	20,949	9.2%
CHLORPYRIFOS	14,869	13,048	27,731	18,549	8.1%
ESFENVALERATE	20,317	17,770	17,557	18,548	8.1%
U.S. Total	**177,467**	**240,881**	**265,942**	**228,097**	**Column Total 75.6%**

Source: Proprietary third party data.

The primary insect pests in Washington state cherries include fruit flies, leafrollers, aphids, and San Jose scale. San Jose scale is most destructive on apple and pear, but can be a serious pest of sweet cherry, peach, prune, and other tree fruits.

Table 93. Top Insect Pests in Washington Cherries – Pest Acres 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
FLY, CHERRY FRUIT	99,001	112,068	98,516	103,195	32.0%
FLY, FRUIT	49,613	61,522	42,375	51,170	15.8%
SPOTTED WING DROSOPHILA	35,627	42,208	57,828	45,221	14.0%
LEAFROLLER	43,462	61,104	28,453	44,340	13.7%
FLY, WESTERN CHERRY FRUIT	44,513	17,570	52,724	38,269	11.8%
APHID, BLACK CHERRY	30,526	32,739	17,608	26,958	8.3%
SCALE, SAN JOSE	18,303	19,258	24,931	20,831	6.4%
U.S. Total	**401,776**	**455,205**	**462,673**	**439,884**	**Column Total 102.2%**

Source: Proprietary third party data.

Washington cherry growers primarily used chlorpyrifos to control San Jose scale, leafrollers, and aphids. Chlorpyrifos and petroleum oil were the primary insecticides used for San Jose scale control, however, there was some limited use of methidathion and pyriproxyfen.

Table 94. Leading Insecticide Active Ingredients Used in Washington State Cherries – Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
SPINOSYN	108,632	79,621	82,189	90,147	27.9%
IMIDACLOPRID	49,540	62,935	55,684	56,053	17.4%
PETROLEUM OIL	42,162	33,828	43,879	39,956	12.4%
SPINETORAM	20,284	36,199	26,065	27,516	8.5%
CHLORPYRIFOS	17,569	16,985	19,503	18,019	5.6%
MALATHION	20,169	3,701	27,482	17,117	5.3%
U.S. Total	**328,655**	**304,672**	**335,519**	**322948**	**Column Total 77.0%**

Source: Proprietary third party data.

19.1.3 Benefits of Chlorpyrifos in Cherries

- Chlorpyrifos is the insecticide most used for control of San Jose scale in Washington state cherries, and American plum borer, and peachtree borer in Michigan cherries
- Effective control of primary insect pests in cherries including plum curculio, green fruitworm, leafrollers, and San Jose scale as well as other economically important insect pests.
- Broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.
- Cost effective.

19.1.4 Chlorpyrifos Formulations, Rates, and Applications

The formulations listed for controlling insect pests in cherries include Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, Cobalt, and Cobalt Advanced.

Location: ID, OR, WA

- Pests: leafrollers, San Jose scale
- Application Type: air blast
- Application Method: broadcast
- Rate: 2.0 lb a.i./A
- Number of Applications: 1
- Season of Application: dormant/delayed dormant

Location: CA

- Pests: San Jose scale
- Application Type: dormant
- Application Method: airblast
- Rate: 2.0 lb a.i./A
- Number of Applications: 1 per year
- Season of Application: dormant

Location: CA

- Pests: American plum borer, greater and lesser peach tree borer
- Application Type: post harvest, avoid contact with foliage
- Application Method: directed trunk spray
- Rate: 1.3 – 3.0 lb a.i./A
- Number of Applications: 2 – 3 per year
- Season of Application: late season

Location: MI, PA, NY

- Pests: American plum borer
- Application Type: spray
- Application Method: trunk spray
- Rate: 0.75 lb a.i./A
- Number of Applications: one application per season
- Season of Application: Petal fall application (spring)
- Alternatives: No chemical or non-chemical alternative

Location: MI, PA, NY

- Pests: peachtree borer
- Application Type: spray
- Application Method: trunk spray
- Rate: 0.75 lb a.i./A
- Number of Applications: 1 application per season
- Season of Application: apply Lorsban timed for peach tree borer moth flights (late June in Michigan)
- Alternatives: no chemical or non-chemical alternative

Location: MI, PA, NY

- Crop: sour cherry
- Pests: green fruitworm (excellent), cherry fruit fly (good), plum curculio (good)
- Application Type: spray
- Application Method: foliar applications
- Rate: 1.0-1.5 lb a.i./A
- Number of Applications: 8 application per season
- Season of Application: dormant through last cover (entire season)

Location: MI, PA, NY

- Product: Lorsban 50W and Lorsban 75WG formulations only
- Crop: sweet cherry
- Pests: green fruitworm (excellent), cherry fruit fly (good), plum curculio (good)
- Application Type: spray
- Application Method: foliar applications
- Rate: 1.0-1.5 lb a.i./A
- Number of Applications: 1 application per season
- Season of Application: dormant through last cover (entire season)

Table 95. Leading Chemical Treatments for Insect Control in Cherries.

Note: Information in the "Benefits, Application, Use and Efficacy" section reflect opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, others	-All pest complex -Reliable broad spectrum to control cherry fruit fly, plum curculio, green fruitworm and other arthropods. -Effective on borers. -Broad spectrum. -Group 1B MOA.
Chlorpyrifos + Gamma-Cyhalothrin/ Chlorpyrifos + Lambda-Cyhalothrin	Cobalt/ Cobalt Advanced	-Dormant/delayed dormant sprays for borers. -Group 1B and 3A MOA.
Esfenvalerate	Asana	-Controls green fruitworm (excellent), cherry fruit fly (good), plum curculio (good). -Broad spectrum. -Group 3A MOA.
Imidacloprid	Several	-Controls San Jose scale and cherry fruit fly. -Suppresses plumb curculio. -Group 4A MOA.
Methidathion	Supracide	-Controls San Jose scale. -Group 1B MOA.
Petroleum/Horticultural Mineral Oil	Several	-Effective on soft-bodied insects (e.g., scale, mite eggs).
Phosmet	Imidan	-Controls plum curculio and cherry fruit fly (excellent). -Group 1B MOA.
Pyriproxyfen	Esteem, Seize	-Controls San Jose scale. -Dormant/delayed, dormant application. -Group 7C MOA.
Spinosad	Entrust	-Controls green fruitworm (excellent). -Group 6 MOA.
Spinosad	Naturalyte	-Controls cherry fruit fly (excellent control of adult flies). -Group 6 MOA.
Spinetoram	Delegate	-Controls green fruitworm (excellent), cherry fruit fly (fair), plum curculio (fair). -Group 6 MOA.
Thiamethoxam	Actara	-Controls cherry fruit fly, plum curculio, aphids and thrips. -Group 4A MOA.
Zeta-Cypermethrin	Mustang, others	Controls green fruitworm (excellent), cherry fruit fly (good), plum curculio (good). -Group 3A MOA.

19.1.5 Non-Chemical Alternatives

A number of natural enemies help suppress pest populations, however, there are currently no practical non-chemical control alternatives effective for management of the target pests noted in cherries.

19.1.6 Expert Perspectives

Following is a selection of excerpts from a grower organization and university specialist, who responded to the EPA's request for input by explaining why they considered chlorpyrifos essential for protecting crops. Submissions to the docket are public information, and have been posted by the EPA at www.regulations.gov, docket number EPA-HQ-OPP-2007-1005. Growers also commented during public comment periods in 2011 (EPA-HQ-OPP-2008-0850-0025) and 2015 (EPA-HQ-OPP-0850-0224).

"Tart and sweet cherries are important crops in Michigan. The state grows 75 percent of the nation's tart cherries, and we have 7,500 acres of sweet cherries in production. Although these two cherries are different species, they have an indistinguishable pest complex.... Borers feed on tree cambium, and an infested four-to-six-inch limb will become unproductive within two years. A severe borer infestation can result in outright tree mortality, especially in young trees.... The primary means for borer control in cherry is chlorpyrifos.... Growers use borer insecticide sprays in conjunction with orchard monitoring techniques that utilize pheromone-based traps.... [B]ased on chemical trials...we can safely say that [chlorpyrifos] is currently the only registered insecticide that provides reliable control of the borer complex.... Without chlorpyrifos, the Michigan cherry industry would suffer tremendous losses in production, yield and orchard acreage." – Dr. Nikki Rothwell, Northwest Michigan Horticultural Research Station

"Chlorpyrifos is the best material available to growers to control borers in cherry orchards (American plum borer, lesser peach tree borer and greater peach tree borer). In fact, I would argue that it's the only material that we have available today to successfully control these insects.... Borers are a serious problem that can devastate an orchard.... Chlorpyrifos is a key material for cherry farmers today and needs to be part of the IPM [Integrated Pest Management] tool box for growers. Chlorpyrifos is an essential tool that provides growers with dependable control of the borer complex that attack cherry orchards. Growers need effective tools that work. Without effective tools, orchards will collapse and die over a very short period of time." – Cherry Marketing Institute, Inc.

19.2 <u>Peaches and Nectarines</u>

An average of 110,287 acres of peaches was grown annually in the U.S. in 2012-2014, a 25% decrease from the 2004-2007 average of 145,930 acres. Three states, California, South Carolina, and Georgia lead the way in peach production, with California producing 49% of peaches in 2014. Nearly 23,000 acres of nectarines were grown nationwide in 2014, with nearly all produced in California (USDA, NASS).

Table 96. U.S. Peach Production – Acres Grown 2012-2014.

State	Acres Grown			
	2012	2013	2014	2012-2014 Average
CALIFORNIA	54,281	54,281	49,641	52,734
SOUTH CAROLINA	19,623	19,623	16,428	18,558
GEORGIA	12,876	12,876	12,876	12,876
NEW JERSEY	5,359	5,359	5,050	5,256
PENNSYLVANIA	5,246	5,246	4,694	5,062
TEXAS	5,088	5,088	4,833	5,003
OTHER STATES	11,390	11,390	9,614	10,798
U.S. Total	**113,863**	**113,863**	**103,136**	**110,287**

Source: Third party proprietary data.

19.2.1 Chlorpyrifos Use

Chlorpyrifos was the fifth most-used active ingredient for the control of insect pests in peaches nationwide. Chlorpyrifos was one of the most-used active ingredients for controlling insect pests in peaches in South Carolina, and represented nearly 12.6% of all active ingredient treated acres in the state. Little chlorpyrifos was used in California peaches.

Table 97. Leading Insecticide Active Ingredients Used in Peaches – Acres Treated 2012–2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
PETROLEUM OIL	83,336	93,866	67,261	81,487	13.2%
PHOSMET	100,448	81,948	48,726	77,040	12.5%
ESFENVALERATE	74,054	71,945	60,639	68,880	11.1%
CYFLUTHRIN	42,964	52,275	52,569	49,269	8.0%
CHLORPYRIFOS	29,401	47,849	22,887	33,379	5.4%
CYHALOTHRIN-LAMBDA	28,693	32,478	34,147	31,773	5.1%
CHLORANTRANILIPROLE	26,499	28,529	33,366	29,465	4.8%
U.S. Total	**645,158**	**683,965**	**524,161**	**617,761**	**Column Total 60.1%**

Source: Proprietary third party data.

Growers used an average of 38,579 lb a.i. of chlorpyrifos annually to control insect pests in peaches in 2012-2014, a 51% decrease in average annual use from 2003-2007 (79,380 lb a.i.). The decrease in chlorpyrifos use resulted from the progressive decline in peach acres, and the introduction of new insecticides.

Table 98. Chlorpyrifos Use in Peaches – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	29,401	47,849	22,887	33,379
Lb a.i. Applied	34,701	52,921	28,114	38,579

Source: Proprietary third party data.

19.2.2 Target Pests

While oriental fruit moth, stink bug and twig borers are the top target pests in peaches, other secondary insect pests such as San Jose scale, peach tree borer, and lesser peach tree borer can damage thousands of acres of peaches. Chlorpyrifos was used to control this secondary group of economically important insect pests.

Table 99. Top Insect Pests in Peaches – Pest Acres 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
MOTH, ORIENTAL FRUIT	141,066	201,997	177,527	173,530	28.1%
BORER, TWIG	110,789	141,281	142,605	131,558	21.3%
BUG, STINK	128,910	150,871	75,619	118,467	19.2%
CURCULIO, PLUM	130,875	115,272	75,030	107,059	17.3%
BUG, TARNISHED PLANT	102,077	90,828	12,872	68,593	11.1%
SCALE, SAN JOSE	38,950	55,939	37,909	44,266	7.2%
SCALE	37,947	42,373	42,682	41,001	6.6%
BORER, PEACH TREE AND LESSER PEACH TREE	35,451	32,884	9,630	25,988	4.2%
U.S. Total	**985,092**	**1,172,780**	**822,912**	**993,595**	**Column Total 115.0%**

Source: Proprietary third party data.

19.2.2.1 Peach Tree Borer and Lesser Peach Tree Borer

There are two species of borers that can be harmful to peach trees: the lesser peach tree borer and the peach tree borer. The peach tree borer attacks healthy bark near the soil line, (just below the ground line or lower 12 inches of the trunk). Peach tree borer injury occurs a few inches above/below the ground. Lesser peach tree borer injury often occurs in peach tree borer wounds, but may also occur in any other spot above ground where the larvae can get under dead bark, and feed on growing inner bark. The wound expands rapidly, and limbs or trunks may be girdled. Open wounds permit entry of disease organisms that may also kill live tissue or decay the heartwood. [1].

Chlorpyrifos is the leading insecticide active ingredient used for control of both the lesser peach borer and the peach tree borer. Chlorpyrifos was used to control peach tree borer and lesser peach tree borer on an average of 19,744 acres annually in 2012-2014, and was used on 75% of the acres treated for these pests.

19.2.2.2 San Jose Scale in Peaches

San Jose scale causes injury by feeding on twigs, branches, and fruit; they may also inject salivary toxins while feeding. Heavy populations on the bark can cause gumming and kill twigs, branches, and entire trees if left uncontrolled [2].

Chlorpyrifos is the second most-used active ingredient (after petroleum oil) for San Jose scale control in peaches.

19.2.3 Benefits of Chlorpyrifos in Peaches

- Chlorpyrifos is the insecticide most used for control of peach tree borer and lesser peach tree borer, and the second most-used product for control of San Jose scale.
- Effective control of San Jose scale, peach tree borer, and lesser peach tree borer as well as other economically important insect pests.
- Provides broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.
- Cost effective.

19.2.4 Chlorpyrifos Formulations, Rates, and Applications

Chlorpyrifos is used in several formulations to effectively control insect pests in peaches and nectarines including Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, Cobalt, and Cobalt Advanced.

Location: ID, OR, WA

- Pests: leafrollers, San Jose scale
- Application Type: air blast
- Application Method: broadcast
- Rate: 2 lb a.i./A
- Number of Applications: 1
- Season of Application: dormant/delayed dormant

Location: CA

- Pests: peach twig borer, San Jose scale, European red mite
- Application Type: dormant
- Application Method: airblast
- Rate: 2 lb a.i./A
- Number of Applications: 1
- Season of Application: dormant (December-January)

Location: All peach producing states

- Pests: peach tree borer
- Application Type: handgun
- Application Method: trunk spray
- Rate: 0.25 – 2.0 lb a.i./A
- Number of Applications: 1
- Season of Application: timed for emergence of peachtree borers
- Alternatives: none in Northeast

Table 100. Leading Chemical Treatments for Insect Control in Peaches.

Note: Information in the "Benefits, Application, Use and Efficacy" section reflect opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, others	-Very effective in controlling scale and borers. -No other alternatives for peach tree borer control in Northeast. -Broad spectrum. -Group 1B MOA.
Chlorpyrifos + Gamma-Cyhalothrin/ Chlorpyrifos + Lambda-Cyhalothrin	Cobalt/ Cobalt Advanced	-Trunk spray or preplant dip for peach tree borer control and as dormant/delayed dormant sprays. -Group 1B and 3A MOA.
Esfenvalerate	Asana	-Dormant for peach twig borer. -Group 3A MOA.
Methidathion	Supracide	-Dormant for peach twig borer. -Group 1B MOA.
Petroleum/Horticultural Mineral Oil	Several	-Effective on soft-bodied insects (e.g., scale, mite eggs).

Active Ingredient	Brand Names	Application, Use, and Efficacy
Pyriproxyfen	Esteem, Seize	-Effective on San Jose scale. -Group 7C MOA.

19.2.5 Non-Chemical Alternatives

A number of natural enemies help suppress pest populations, however, there are currently no practical, non-chemical control alternatives effective for management of the target pests mentioned in peaches.

19.2.6 Expert Perspectives

The following is a selection of excerpts from university specialists, who responded to the EPA's request for input by explaining why they considered chlorpyrifos essential for protecting crops. Submissions to the docket are public information, and have been posted by the EPA at www.regulations.gov, docket number EPA-HQ-OPP-2007-1005. Growers also commented during public comment periods in 2011 (EPA-HQ-OPP-2008-0850-0025) and 2015 (EPA-HQ-OPP-0850-0224).

"Chlorpyrifos is an absolutely key material for southeastern peach growers. Policy-driven incentives to either eliminate or restrict its use in peaches would further degrade grower options for successfully managing lesser peachtree borer. It would almost certainly further increase pyrethroid use. Any restrictions on the availability of chlorpyrifos to southeastern peach growers would be ill advised." – Dan Horton, Professor of Entomology, University of Georgia; and Ted Cottrell, research scientist, U.S. Department of Agriculture

"Peachtree borer has historically been regarded as the southeastern U.S.'s key borer species, as uncontrolled peachtree borer infestations will debilitate and kill trees more rapidly than the lesser peachtree borer. Control of peachtree borer in southeastern peach production has been, and remains, almost entirely dependent on post-harvest application of chlorpyrifos.... Pheromone mating disruption, or substitution of either endosulfan or pyrethroids are dramatically inferior to the current use of chlorpyrifos." – Dan L. Horton, University of Georgia, Entomology

19.3 <u>Plums and Prunes</u>

California, the dominant producer of plums, produces more dried plums and prunes than the rest of the world combined. Idaho, Michigan, Oregon, and Washington grow a small acreage of plums and prunes. An average of 86,102 acres of plums and prunes was grown annually in the U.S. in 2012-2014, a 42% decrease from the 145,930 acres grown in 2004.

Table 101. US Plum/Prune Production – Acres Grown 2012-2014.

State	Acres Grown			
	2012	2013	2014	2012-2014 Average
CALIFORNIA	88,009	88,009	74,589	83,536
OTHER STATES	2,600	2,600	2,500	2,567
U.S. Total	**90,609**	**90,609**	**77,089**	**86,102**

Source: California – Third party proprietary data. Other states – USDA, NASS.

19.3.1 Chlorpyrifos Use

Although chlorpyrifos use only averaged 1.6% of all active ingredient acres treated on this crop in 2012-2014, it is an important tool in the U.S. plumb and prune production systems.

Table 102. Leading Insecticide Active Ingredients Used in Plums and Prunes – Acres Treated 2012–2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
ESFENVALERATE	55,958	57,688	48,354	54,000	26.9%
PETROLEUM OIL	62,406	52,148	36,874	50,476	25.1%
ABAMECTIN	24,175	32,018	25,142	27,112	13.5%
CHLORANTRANILIPROLE	18,534	7,304	3,786	9,875	4.9%
PYRIPROXYFEN	8,976	5,887	11,210	8,691	4.3%
SPINETORAM	2,252	3,010	9,985	5,082	2.5%
HEXYTHIAZOX	2,437	5,448	7,235	5,040	2.5%
METHOXYFENOZIDE	2,099	9,603	2,155	4,619	2.3%
IMIDACLOPRID	6,576	4,103	3,003	4,560	2.3%
BACILLUS THURINGIENSIS	7,017	2,559	3,754	4,443	2.2%
CHLORPYRIFOS	4,893	3,666	1,306	3,289	1.6%
U.S. Total	**222,678**	**208,548**	**171,554**	**200,927**	**Column Total 88.2%**

Source: Proprietary third party data.

Growers used an average of 5,294 lb a.i. of chlorpyrifos annually to control insect pests in plums and prunes in 2012-2014, an 85% decrease in average annual use from 2003-2007 (39,432 lb a.i.). The decrease in chlorpyrifos use resulted from the progressive decline in plum and prune acreage, and the introduction and use of new insecticides to control twig borer, especially in California.

Table 103. Chlorpyrifos Use in Plumbs and Prunes – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	4,893	3,666	1,306	3,289
Lbs a.i. Applied	8,034	5,369	2,479	5,294

Source: Proprietary third party data.

Proprietary third party data indicated that California growers used an average of 3,835 lb a.i. of chlorpyrifos annually in 2012-4014, an 89% decrease from average annual use in 2003-2007 (35,432 lb a.i). Some variation in acres treated and lbs a.i. applied were found comparing CDPR and proprietary third party data for chlorpyrifos use on plums and prunes. CDPR reported 60% less chlorpyrifos average annual use in 2012-2014 (1,557 lb a.i.) than the third party proprietary data.

Table 104. Chlorpyrifos Use in California Plums and Prunes – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	Data Source	2012	2013	2014	2012-2014 Average
Acres Treated	CDPR	1,176	973	657	935
	Proprietary third party	4,893	3,666	1,306	3,288
Lb a.i. Applied	CDPR	2,097	1,577	997	1,557
	Proprietary third party	4,648	3,569	3,289	3,835

19.3.2 Target Pests

The most troublesome insect pests in California plums include twig borers, San Jose scale, aphids, and mites. Chlorpyrifos was primarily used for control of San Jose scale and other scale insects. San Jose scale is one of the most destructive pests of stone fruits in the U.S. San Jose scale can infest branches, shoots, leaves, and fruit. Adults and nymphs suck plant juices and cause considerable damage. They have been known to seriously weaken branches and main scaffold limbs, causing permanent injury to mature trees. Crawlers settling on fruit may cause fruit spotting [4].

Table 105. Top Insect Pests in Plums and Prunes – Pest Acres 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
BORER, TWIG	58,682	76,108	43,348	59,379	29.6%
SCALE, SAN JOSE	43,549	32,588	21,372	32,503	16.2%
APHID	36,192	27,700	32,985	32,292	16.1%
MITE, 2-SPOTTED	36,255	31,479	15,624	27,786	13.8%
SCALE	22,852	12,404	13,839	16,365	8.1%
U.S. Total	**279,244**	**269,270**	**201,258**	**249,924**	**Column Total 83.8%**

Source: Proprietary third party data.

Chlorpyrifos was the third most-used insecticide active ingredient for control of San Jose scale. Chlorpyrifos is typically mixed with oil for scale control.

Table 106. Leading Insecticide Active Ingredients Used to Control San Jose Scale in Plums and Prunes – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
PETROLEUM OIL	30,942	18,256	6,765	18,654	57.4%
PYRIPROXYFEN	3,464	5,027	10,666	6,385	19.6%
CHLORPYRIFOS	3,982	3,022	657	2,553	7.9%
ESFENVALERATE	3,910	3,031	436	2,459	7.6%
SPIROTETRAMAT	1,251	2,267	1,077	1,532	4.7%
U.S. Total	**43,549**	**32,588**	**21,372**	**32,503**	**Column Total 97.2%**

Source: Proprietary third party data.

19.3.3 Benefits of Chlorpyrifos in Plums and Prunes

- Effective control of primary insect pests in plums and prunes, including San Jose scale and twig borer, as well as other economically important insect pests.
- Broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.
- Cost effective.

19.3.4 Chlorpyrifos Formulations, Rates, and Applications

Formulations listed for controlling insect pests in plums include Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, Cobalt, and Cobalt Advanced.

Location: ID, OR, WA

- Pests: San Jose scale
- Application Type: air blast
- Application Method: broadcast
- Rate: 2 lb a.i./A
- Number and season of Applications: 1, dormant/delayed dormant

Location: CA

- Pests: peach twig borer, San Jose scale, European red mite
- Application Type: dormant
- Application Method: airblast
- Rate: 2 lb a.i./A
- Number of Applications: 1
- Season of Application: dormant (December-January)

Table 107. Leading Chemical Treatments for Insect Control in Plums and Prunes.

Note: Information in the "Benefits, Application, Use and Efficacy" section reflect opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, others	-Dormant/delayed dormant controls San Jose scale, borers and European red mites. -Broad spectrum. -Group 1B MOA.
Chlorpyrifos + Gamma-Cyhalothrin/ Chlorpyrifos + Lambda-Cyhalothrin	Cobalt/ Cobalt Advanced	-Dormant/delayed dormant controls borers. -Group 1B and 3A MOA.
Esfenvalerate	Asana	-Controls San Jose scale. Dormant/delayed dormant controls twig borer. -Group 3A MOA.
Methidathion	Supracide	-Controls San Jose scale. -Group 1B MOA.
Petroleum/Horticultural Mineral Oil	Several	-Effective on soft-bodied insects (e.g., scale, mite eggs).
Pyriproxyfen	Esteem, Seize	-Controls San Jose scale. -Group 7C MOA.
Spirotetramat	Movento	-Controls San Jose scale and aphids. -Group 23 MOA

19.3.5 Non-Chemical Alternatives

A number of natural enemies help suppress pest populations, however, there are currently no practical, non-chemical control alternatives effective for management of the target pests mentioned in plums and prunes.

19.4 Apples

The U.S. is the world's second-largest producer of apples, behind China. An average of over 327,354 acres of apples was grown annually in the U.S. in 2012-2014, a 17% decrease from the 2003-2007 average of 391,812 acres. Apples are grown commercially in 32 states. The top six apple-producing states are Washington, New York, Michigan, Pennsylvania, California, and Virginia. U.S. apple production trails only oranges and grapes in the amount of U.S. acreage committed to fruit production.

Apples are the number one cash crop in Washington state according to the Washington State Department of Agriculture. Approximately one out of every four apples harvested in the U.S. is exported. Almost 67% of the apples grown in the U.S. are sold as fresh fruit The rest of the apples are processed into apple products including juice and fresh slices [4].

Table 108. U.S. Apple Production – Acres Grown 2012-2014.

Region	State	Acres Grown			
		2012	2013	2014	2012-2014 Average
West	WASHINGTON	157,656	157,656	174,008	163,107
	CALIFORNIA	18,938	18,938	17,079	18,318
	OREGON	5,195	5,195	5,754	5,381
Atlantic	NEW YORK	49,966	49,966	45,967	48,633
	PENNSYLVANIA	23,778	23,778	22,873	23,476
	VIRGINIA	13,544	13,544	11,751	12,946
	NORTH CAROLINA	4,461	4,461	5,856	4,926
	WEST VIRGINIA	4,083	4,083	4,764	4,310
Midwest	MICHIGAN	41,980	41,980	42,002	41,987
	OHIO	3,980	3,980	4,845	4,268
Total U.S.		**323,581**	**323,581**	**334,899**	**327,354**

Source: Proprietary third party data.

19.4.1 Chlorpyrifos Use

Chlorpyrifos is one of the leading active ingredients used to control insect pests in apples. Active ingredient acres treated annually with chlorpyrifos averaged 211,922 or 7.3% of total treated acres in 2012-2014, a 21% decrease from 2007 (266,822 treated acres).

Table 109. Leading Insecticide Active Ingredients Used in Apples – Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
PETROLEUM OIL	619,893	430,517	405,870	485,427	16.7%
CHLORANTRANILIPROLE	251,841	310,708	388,577	317,042	10.9%
SPINETORAM	153,447	285,666	268,547	235,887	8.1%
CHLORPYRIFOS	194,737	227,011	214,017	211,922	7.3%
ACETAMIPRID	237,634	174,932	206,563	206,376	7.1%
IMIDACLOPRID	138,843	219,575	179,880	179,432	6.2%
PHOSMET	100,351	215,992	162,867	159,737	5.5%
CYHALOTHRIN-LAMBDA	100,984	132,469	130,684	121,379	4.2%
U.S. Total	**2,676,361**	**2,987,888**	**3,064,402**	**2,909,550**	**Column Total 65.9%**

Source: Proprietary third party data.

Growers used an average of 339,277 lb a.i. of chlorpyrifos annually to control insect pests in apples in 2012-2014, an 18% decrease from average annual use in 2003-2007 (414,600 lb a.i.). The decrease in chlorpyrifos use primarily resulted from the progressive decline in apple acreage.

Table 110. Chlorpyrifos Use in Apples – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	194,737	227,011	214,017	211,922
Lb a.i. Applied	294,264	367,249	326,317	329,277

Source: Proprietary third party data.

19.4.2 Target Pests

While codling moth is by far the number one insect pest in apples, other insect pests like leafrollers, oriental fruit moth, aphids, scale, and mites can damage thousands of acres of apples.

Table 111. Top Insect Pests in Apples – Pest Acres 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
MOTH, CODLING	927,341	1,307,578	1,253,905	1,162,941	40.0%
LEAFROLLER	352,115	414,918	331,050	366,028	12.6%
MOTH, ORIENTAL FRUIT	296,010	275,065	365,630	312,235	10.7%
APHID	233,226	266,761	211,497	237,161	8.2%
SCALE	372,713	83,642	196,231	217,529	7.5%
MITE	214,846	215,371	158,014	196,077	6.7%
SCALE, SAN JOSE	187,951	166,840	213,710	189,500	6.5%
CURCULIO, PLUM	111,968	179,739	231,084	174,264	6.0%
U.S. Total	**4,227,855**	**4,699,559**	**5,177,861**	**4,701,758**	**Column Total 98.2%**

Source: Proprietary third party data.

19.4.2.1 San Jose Scale

San Jose scale is an extremely important pest of apples, pears, peaches, and plums. Discoloration on the fruit is caused by a toxin injected from this sucking insect as it feeds. Left uncontrolled, San Jose scale can kill the entire tree in a couple of years [5].

Chlorpyrifos was the leading active ingredient used to control scale in apples, and was used on 47.8% of the pest acres treated for scale in 2012-2014.

Table 112. Leading Insecticide Active Ingredients Used to Control Scale in Apples – Pest Acres 2012-2014.

Insecticide	Pest Acres				% of Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CHLORPYRIFOS	86,599	79,760	106,079	90,813	47.9%
PETROLEUM OIL	55,311	61,029	70,106	62,149	32.8%
PYRIPROXYFEN	5,605	18,979	6,533	10,373	5.5%
SPIROTETRAMAT	1,734	480	13,276	5,164	2.7%
U.S. Total	**187,951**	**166,840**	**213,710**	**189,500**	**Column Total 88.9%**

Source: Proprietary third party data.

19.4.2.2 Leafrollers

Leafrollers (oblique-banded, red-banded, fruit tree leafroller, *Pandemis*) are among the most important pests of apples in the northeastern part of the U.S. The larval stage for these pests can damage fruit from April through early August.

Chlorpyrifos was the fifth most-used active ingredient to control leafrollers in apples, and was used on 9.1% of the pest acres treated for leafrollers in 2012-2014.

Table 113. Leading Insecticide Active Ingredients Used to Control Leafrollers in Apples – Pest Acres 2012-2014.

Insecticide	Pest Acres				% of Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CHLORANTRANILIPROLE	46,430	65,656	72,312	61,466	16.8%
METHOXYFENOZIDE	58,459	17,077	44,645	40,060	10.9%
SPINETORAM	9,455	56,172	49,343	38,324	10.5%
PETROLEUM OIL	65,325	27,948	16,677	36,650	10.0%
CHLORPYRIFOS	21,806	47,824	29,932	33,188	9.1%
CARBARYL	47,835	22,876	14,865	28,525	7.8%
U.S. Total	**352,115**	**414,918**	**331,050**	**366,028**	**Column Total 65.1%**

Source: Proprietary third party data.

19.4.2.3 Aphids

Aphids can cause terminal leaves to curl downward, and may become sticky with honeydew secreted by the aphids. This honeydew may drip onto the fruit, causing russet spots and promote growth of black sooty mold. Highly infested shoots of young trees can be stunted or malformed.

Chlorpyrifos is the fourth most-used active ingredient to control aphids in apples, and was used on 11.9% of the pest acres treated for aphids in 2012-2014.

Table 114. Leading Insecticide Active Ingredients Used to Control Aphids in Apples – Pest Acres 2012-2014.

Insecticide	Pest Acres				% of Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
IMIDACLOPRID	32,385	57,291	53,525	47,734	20.1%
ACETAMIPRID	53,305	29,929	31,356	38,197	16.1%
PETROLEUM OIL	48,519	14,648	27,585	30,250	12.8%
CHLORPYRIFOS	11,901	43,172	29,874	28,315	11.9%
CHLORANTRANILIPROLE	6,976	49,305	12,698	22,993	9.7%
U.S. Total	**233,226**	**266,761**	**211,497**	**237,161**	**Column Total 70.6%**

Source: Proprietary third party data.

Chlorpyrifos is the preferred product in the Pacific Northwest for use as a dormant or delayed dormant treatment to control overwintering generations of a number of insect pests including oblique-banded and red-banded leafrollers, *Pandemis* leafrollers, and San Jose scale. Chlorpyrifos is typically used in combination with a 1-2% solution of oil. This combination continues to provide effective control of overwinter leafroller larvae, long after the applications are made, by imparting some level of mortality inside the hibernacula (overwintering shelter). Chlorpyrifos used with the oil solution also provides control of San Jose scale populations and early colonies of rosy apple aphid. Control of these pests during the dormant/delayed dormant timing is critical toward their overall in-season management.

19.4.3 Benefits of Chlorpyrifos in Apples

- Chlorpyrifos is the insecticide most used for control of San Jose scale.
- Preferred product in the Pacific Northwest for use as a dormant or delayed dormant treatment to control overwintering generations of a number of insect pests including oblique-banded and red-banded leafrollers, *Pandemis* leafrollers, and San Jose scale.

- Effective control of several primary insect pests in apples including leafrollers, aphids, and scale as well as other economically important insect pests.
- Provides broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.
- Cost effective.

19.4.4 Chlorpyrifos Formulations, Rates, and Applications

The formulations listed for treating apple include Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, Cobalt, and Cobalt Advanced.

Location: Pacific Northwest

- Pests: leafroller, San Jose scale, rosy apple aphid
- Application Type: air blast
- Application Method: broadcast
- Rate: 2.0 lb a.i./A (Lorsban-4E) and 1.9 lb a.i./A (Lorsban Advanced)
- Number of Applications: 1
- Season of Application: dormant/delayed dormant

Location: Northeast and Midwest (MI, OH, NY, PA, VA, MD, MA, VT, ME, WI, NC)

- Pests: San Jose Scale, rosy apple aphid
- Application Type: foliar
- Application Method: airblast sprayer
- Rate: 1.0-2.0 lb a.i./A
- Number of Applications: 1
- Season of Application: dormant or delayed dormant application (green tip to early tight cluster)
- Alternative: no non-chemical alternatives are available to treat the over-wintering insects

Table 115. Leading Chemical Treatments for Insect Control in Apples.

Note: Information in the "Benefits, Application, Use and Efficacy" section reflect opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, Others	-Highly effective in combination with dormant oil as delayed dormant spray for control of scale insects and overwintering leafrollers. -Broad spectrum. -Group 1B MOA.
Chlorpyrifos + Gamma-Cyhalothrin/ Chlorpyrifos + Lambda-Cyhalothrin	Cobalt/ Cobalt Advanced	-Highly effective in combination with dormant oil as delayed dormant spray for control of scale insects. -Group 1B and 3A MOA.
Acetamiprid	Assail	-Controls rosy apple aphid, pre-bloom and summer application (excellent). -Group 4A MOA.
Bacillus thuringiensis (Bt)	Several	-Must make two applications around "bloom" period to be effective; primarily utilized as "bloom" spray. -Group 11A MOA.
Buprofezin	Centaur	-Controls San Jose scale, summer application (good). -Group 16 MOA.
Chlorantraniliprole	Altacor	-Post-bloom application; labeled for oblique-banded leafroller only. -Group 28 MOA.
Emamectin benzoate	Proclaim	-Post-bloom application; effective against oblique-banded leafroller and *pandemis* leafrollers. -Group 6 MOA.
Flubendiamide	Belt	-Post-bloom application; effective against oblique-banded leafroller and *pandemis* leafrollers. -Group 28 MOA.
Methoxyfenozide	Intrepid	-Post-bloom application; effective against oblique-banded leafroller and *pandemis* leafrollers. -Group 18 MOA.
Petroleum/Horticultural Mineral Oil	Several	-Effective on soft-bodied insects (e.g., scale, mite eggs).
Pyrethroids	Several	-Post-bloom application; effective but not recommended due to disruptive mortality of predatory mites in orchard system. -Use not "sanctioned" by official spray guides. -Group 3A MOA.
Pyriproxyfen	Esteem	-Controls San Jose scale, rosy apple aphid, dormant and summer application (good).

Active Ingredient	Brand Names	Application, Use, and Efficacy
		-Group 7C MOA.
Spinetoram	Delegate	-Post-bloom application; highly effective on oblique-banded leafrollers and *pandemis* leafrollers. -Group 6 MOA.
Spirotetramat	Movento	-Controls San Jose scale, aphids and rust mites. -Group 23 MOA.
Thiacloprid	Calypso	-Controls rosy apple aphid, pre-bloom and summer application (excellent). -Group 4A MOA.

19.4.5 Non-Chemical Alternatives

Pheromone disruption is under development for oblique-banded leafrollers in the Pacific Northwest. No commercial successes have yet been achieved. Mating disruption for codling moth management in apples has been the focus of the majority of research efforts and funding. The commercial success of codling moth disruption is serving as enabling technology for leafroller mating disruption. Approximately 90% of bearing apple acreage in Washington is under a mating disruption program for codling moth.

Granulosis virus – Codling moth virus products (e.g., Cyd-X) have been used with some success in organic systems. The use of the virus requires a long-term management approach as effective control of codling moth is usually not achieved in one season.

Entomophagous nematodes – Parasitic nematodes have been evaluated both academically and commercially for control of Lepidoptera pests of apples, especially codling moth and leafrollers. No consistent commercially acceptable control has been achieved by this means. In addition, commercially developed products based on entomophagous nematodes have been difficult to apply, have had poor shelf life, and have had a very high cost structure relative to standard insecticides.

19.4.6 Grower Perspective

The following is an excerpt from a grower organization which responded to the EPA's request for input by explaining why they considered chlorpyrifos essential for protecting crops. Submissions to the docket are public information and have been posted by the EPA at www.regulations.gov, docket number EPAHQ-OPP-2007-1005. Growers also commented during public comment periods in 2011 (EPA-HQ-OPP-2008-0850-0025) and 2015 (EPA-HQ-OPP-0850-0224).

"Chlorpyrifos is one of the most versatile pesticides and is used to control borers, Oriental fruit moth, red-banded leafroller, plant bugs, obliquebanded leafroller, tufted apple bud moth, green fruitworm, plum curculio, green apple aphid, rosy apple aphid, woolly apple aphid, San Jose scale and European apple sawfly. Chlorpyrifos is

considered an excellent choice to control these pests because it effectively controls many target pests simultaneously and it is economical.... While pyrethroids represent a possible alternative for some pests, they are so disruptive to Integrated Pest Management (IPM) they are not considered a viable alternative." – James Cranney, Jr., U.S. Apple Association

19.5 Pears

An average of 54,059 acres of pears was grown annually in the U.S. in 2012-2014, a 20% decrease from the 391,812 acres grown in 2007. Washington and Oregon grow 75% of the nation's total pear production. Pears are the leading tree fruit crop in Oregon and the second largest fruit crop in Washington. Approximately 35% of U.S. pears are exported. About 60% of the U.S. pear crop is sold as fresh and the rest is processed, primarily in the form of canned product [6]. Less than 5,000 acres of pears are planted in the Northeast apple growing region (Wisconsin through New York and south to North Carolina) (USDA, NASS).

Table 116. U.S. Pear Production – Acres Grown 2012-2014.

State	Acres Grown			
	2012	2013	2014	2012-2014 Average
WASHINGTON	22,856	22,856	23,197	22,970
OREGON	18,416	18,416	15,236	17,356
CALIFORNIA	14,802	14,802	11,595	13,733
Total U.S.	**56,074**	**56,074**	**50,028**	**54,059**

Source: Proprietary third party data.

19.5.1 Chlorpyrifos Use

An average of 13,939 lbs a.i. of chlorpyrifos was used to control insects in pears, a 43% decrease in average annual use from 2003-2007 (29,564 lb a.i.). The decrease in chlorpyrifos use resulted from the progressive decline in pear acreage and the introduction of new insecticides.

Table 117. Chlorpyrifos Use in Pears – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	7,080	3,760	10,660	7,167
Lb a.i. Applied	13,508	7,520	20,789	13,939

Source: Proprietary third party data.

Chlorpyrifos is primarily used for San Jose scale control as a delayed dormant application, for pear psylla control, and in some cases to control leafrollers (oblique-banded, *Pandemis*).

Table 118. Top Insect Pests in Pears – Pest Acres 2012-2014.

Insecticide	Pest Acres				% of Total a.i. Treated Acres (2012-2014
	2012	2013	2014	2012-2014 Average	
PSYLLA, PEAR	488,498	441,364	493,582	474,481	70.4%
MOTH, CODLING	81,744	126,730	102,332	103,602	15.4%
MITE	72,056	75,194	85,491	77,580	11.5%
MITE, 2-SPOTTED	71,670	76,351	69,621	72,547	10.8%
MITE, RUST	41,703	16,947	78,488	45,713	6.8%
MITE, RUST (PEAR)	45,587	49,133	13,605	36,108	5.4%
SCALE	9,307	32,269	51,807	31,128	4.6%
MITE, SPIDER	20,439	40,186	27,680	29,435	4.4%
SCALE, SAN JOSE	44,654	10,137	20,801	25,197	3.7%
U.S. Total	**1,013,344**	**1,015,411**	**1,063,303**	**1,030,686**	**Column Total 132.9%**

Source: Proprietary third party data.

19.5.2 Benefits of Chlorpyrifos in Pears

- Effective control of several primary insect pests in pears, including pear psylla and San Jose scale, as well as other economically important insect pests such as leafrollers.
- Broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.
- Cost effective.

19.5.3 Chlorpyrifos Formulations, Rates, and Applications

Formulations listed for treating pear include Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, Cobalt, and Cobalt Advanced.

Location: OR, WA

- Pests: San Jose scale
- Application Type: air blast

- Application Method: broadcast
- Rate: 2.0 lb a.i./A
- Number of Applications: 1
- Season of Application: dormant/delayed dormant

Location: CA

- Pests: San Jose scale, European red mite
- Application Type: foliar
- Application Method: airblast
- Rate: 2.0 lb a.i./A
- Number of Applications: 1
- Season of Application: dormant

Location: Northeast and Midwest (MI, OH, NY, PA, VA, MD, MA, VT, ME, WI, NC)

- Pests: San Jose scale,
- Application Type: foliar
- Application Method: Airblast sprayer
- Rate: 1.0-2.0 lb a.i./A
- Number of Applications: 1
- Season of Application: dormant or delayed dormant application (green tip to early tight cluster)
- Alternative: no non-chemical alternatives are available to treat the over-wintering insects

Table 119. Leading Chemical Treatments for Insect Control in Pears.

Note: Information in the "Benefits, Application, Use and Efficacy" section reflect opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, others	-Highly effective in combination with dormant oil as delayed dormant spray for control of scale insects and overwintering leafrollers; only major use in pears. -Group 1B MOA.
Chlorpyrifos + Gamma-Cyhalothrin/ Chlorpyrifos _ Lambda-Cyhalothrin	Cobalt/ Cobalt Advanced	-Highly effective in combination with dormant oil as delayed dormant spray for control of scale insects. -Groups 1B and 3A MOA.
Buprofezin	Centaur	-Controls San Jose scale, summer application (good). -Group 16 MOA.
Methidathion	Supracide	-Controls San Jose scale. -Group 1B MOA.
Petroleum/Horticultural	Several	-Effective on soft-bodied insects (e.g., scale, mite

Active Ingredient	Brand Names	Application, Use, and Efficacy
Mineral Oil		eggs).
Pyrethroids	Several	-Effective but not recommended due to disruptive mortality of predatory mites in orchard system. -Use not "sanctioned" by official spray guides. -Group 3A MOA.
Pyriproxyfen	Esteem, Seize	-Controls San Jose scale, dormant. -Group 7C MOA.
Spirotetramat	Movento	-Controls San Jose scale, aphids and rust mites. -Group 23 MOA.

19.5.4 Non-Chemical Alternatives

Granulosis virus – Codling moth virus products (e.g., Cyd-X) have been used with some success in organic systems. The use of this virus requires a long-term management approach as effective control of codling moth is usually not achieved in one season.

Entomophagous nematodes – Parasitic nematodes have been evaluated both academically and commercially for control of Lepidoptera pests of pears, especially codling moths and leafrollers. No consistent commercially acceptable control has been achieved by this means. In addition, commercially developed products based on entomophagous nematodes have been difficult to apply, have had poor shelf life, and have had a very high cost structure relative to standard insecticides.

19.6 References

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20. Sorghum (grain)

20.1 Overview

An average of 7.0 million acres of grain sorghum were grown annually in the U.S. in 2012-2014. Over 90% of grain sorghum was produced in the Plains states.

Table 120. U.S. Grain Sorghum Production – Acres Planted 2012-2014.

State	Acres Planted			
	2012	2013	2014	2012-2014 Average
KANSAS	2,500,008	3,099,997	2,850,000	2,816,668
TEXAS	2,299,988	3,000,000	2,600,000	2,633,329
COLORADO	245,000	399,995	330,000	324,998
OKLAHOMA	260,003	320,000	370,000	316,667
SOUTH DAKOTA	200,000	350,002	230,000	260,001
NEBRASKA	145,000	290,000	170,000	201,667
ARKANSAS	140,000	130,000	170,000	146,667
LOUISIANA	129,999	115,000	100,000	115,000
NEW MEXICO	89,999	124,999	110,000	108,333
MISSOURI	65,000	70,000	85,000	73,333
GEORGIA	55,000	50,000	35,000	46,666
ILLINOIS	30,000	23,000	23,000	25,333
U.S. Total	**6,159,997**	**7,972,992**	**7,073,000**	**7,068,663**

Source: Proprietary third party data.

20.2 Chlorpyrifos Use

Chlorpyrifos was used on an average of 90,853 acres of grain sorghum annually, and was the fifth most-used insecticide active ingredient in 2012-2014. Chlorpyrifos was among the most-used active ingredients for controlling primary grain sorghum insect pests including midge, head worm, yellow sugarcane aphid, and stink bug. Maintaining the availability of chlorpyrifos in the grain sorghum insecticide complex is important for the control of these insect pests, and the viability of long-term resistance management programs.

Table 121. Leading Insecticide Active Ingredients in Grain Sorghum – Acres Treated 2012–2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CYHALOTHRIN-LAMBDA	305,121	382,099	245,249	310,823	28.3%
SULFOXAFLOR	--	--	515,648	171,883	15.6%
CYFLUTHRIN	224,627	94,376	172,239	163,747	14.9%
ZETA-CYPERMETHRIN	227,392	179,434	70,519	159,115	14.5%
CHLORPYRIFOS	92,651	86,656	93,251	90,853	8.3%
DIMETHOATE	132,130	2,690	68,949	67,923	6.2%
U.S. Total	**1,107,594**	**891,830**	**1,295,678**	**1,098,367**	**Column Total 87.8%**

Source: Proprietary third party data. Excluding seed treatment.

Growers used an average of 42,257 lb a.i. of chlorpyrifos annually to control insect pests in grain sorghum in 2012-2014, a 300% increase from average annual use in 2003-2007 (14,191 lb a.i.).

Table 122. Chlorpyrifos Use in Grain Sorghum – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	92,651	86,656	93,251	90,853
Lbs a.i. Applied	39,497	42,532	44,741	42,257

Source: Proprietary third party data.

20.3 Target Pests

Midge, head worm (corn ear worm, fall armyworm, sorghum webworm), yellow sugarcane aphid, and stink bugs were the top target pests in grain sorghum and accounted for 100.5% of the total active ingredient acres. Each causes significant losses in grain sorghum as described below. Chlorpyrifos provides broad spectrum control of a number of insect pests in grain sorghum, and was among the leading active ingredients used to control these economically important insect pests.

Table 123. Top Insect Pests in Grain Sorghum – Acres Treated 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
MIDGE	375,827	284,038	296,838	318,901	29.0%
WORM, HEAD	190,387	382,072	129,214	233,891	21.3%
APHID, YELLOW SUGARCANE	--	--	567,485	189,162	17.2%
BUG, STINK	192,230	244,148	19,794	152,057	13.8%
BUG, RICE STINK	250,718	--	2,906	84,541	7.7%
WORM, CORN EAR	117,870	31,966	9,230	53,022	4.8%
U.S. Total	**1,617,180**	**1,182,384**	**1,592,539**	**1,464,035**	**Column Total 100.5%**

Source: Proprietary third party data. Excluding seed treatments.

20.3.1 Midge

The sorghum midge is potentially the most destructive pest of grain sorghum. Larval feeding causes "blasted" heads resulting in undeveloped seeds. High populations of midge occur in areas where flowering is extended over a long period of time because of staggered planting dates, uneven emergence, or in fields where tillers and side branches, commonly called suckers, develop as a result of stress and produce late heads [1].

Chlorpyrifos was the fourth most-used insecticide active ingredient to control midge in grain sorghum, and was used on 5.4% of the pest acres treated for midge in 2012-2014. Pyrethroids accounted for 92.6% of the pest acres treated for midge in 2012-2014. Chlorpyrifos was the most-used non-pyrethroid insecticide. Effective non-pyrethroid insecticides, like chlorpyrifos, are needed to help manage resistance development.

Table 124. Leading Insecticide Active Ingredients Used to Control Midge in Grain Sorghum – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CYHALOTHRIN-LAMBDA	120,462	180,120	180,994	160,525	50.3%
CYFLUTHRIN	133,714	51,852	74,036	86,534	27.1%
ZETA-CYPERMETHRIN	70,135	3,602	3,690	25,809	8.1%
CHLORPYRIFOS	45,528	--	6,333	17,287	5.4%
ESFENVALERATE	--	41,261	--	13,754	4.3%
U.S. Total	**375,827**	**284,038**	**296,838**	**318,901**	**Column Total 95.3%**

Source: Proprietary third party data. Excluding seed treatments.

20.3.2 Head Worm (Corn Ear Worm, Fall Armyworm, Sorghum Webworm)

Corn earworm, fall armyworm and sorghum webworm are common in sorghum growing areas. Corn earworm and fall armyworm infestations in grain sorghum heads are generally below treatment level except in late crops. Infestations are more damaging in tight headed sorghum varieties than in open heading varieties. Large numbers of webworms, especially in late planted sorghum, can occur in heads where they gnaw circular holes in maturing seed and feed on the starchy contents [1].

Chlorpyrifos was the third most-used insecticide active ingredient to control head worm in grain sorghum, and was used on 23.6% of the pest acres treated for head worm in 2012-2014. Pyrethroids accounted for 69.3% of the pest acres treated for head worm. Chlorpyrifos was the most-used non-pyrethroid insecticide. Effective non-pyrethroid insecticides, like chlorpyrifos, are needed to help manage resistance development.

Table 125. Leading Insecticide Active Ingredients Used to Control Head Worm (Corn Earworm, Fall Armyworm, Sorghum Webworm) in Grain Sorghum – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
ZETA-CYPERMETHRIN	56,798	131,323	3,185	63,769	27.3%
CYHALOTHRIN-LAMBDA	60,874	121,287	6,451	62,871	26.9%
CHLORPYRIFOS	67,953	82,397	15,304	55,218	23.6%
CYFLUTHRIN	--	16,243	46,994	21,079	9.0%
CYHALOTHRIN-GAMMA	4,761	28,132	9,999	14,297	6.1%
U.S. Total	**190,387**	**382,072**	**129,214**	**233,891**	**Column Total 92.9%**

Source: Proprietary third party data. Excluding seed treatment.

20.3.3 Yellow Sugarcane Aphid

Yellow sugarcane aphid were discovered attacking grain sorghum in south Texas in 2013 and have spread northward. They are capable of very high rates of reproduction, and inject a toxin into the plant when feeding which causes seedling plants to turn purple, similar to phosphate deficiency. Mature leaves will be stunted and turn yellow as a result of feeding. Sorghum up to 18 inches tall can be killed by 5 to 10 aphids per leaf, but the aphid is rarely found on plants beyond the 5-leaf stage. The aphid is not expected to overwinter much further north than south Texas, but large numbers of migrants are expected to move north during the growing season [2].

Chlorpyrifos was the second most-used insecticide active ingredient to control yellow sugarcane aphid in grain sorghum, and was used on 10.3% of the pest acres treated for yellow sugarcane aphid in 2014. Sulfoxaflor was, by far, the most-used insecticide in 2014 for yellow sugarcane aphid, and chlorpyrifos use will likely increase in 2016 in response to the revoked registration of sulfoxaflor.

Table 126. Leading Insecticide Active Ingredients Used to Control Yellow Sugarcane Aphid in Grain Sorghum – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2014 Average	
SULFOXAFLOR	--	--	372,855	372,855	65.7%
CHLORPYRIFOS	--	--	58,719	58,719	10.3%
DIMETHOATE	--	--	58,719	58,719	10.3%
ZETA-CYPERMETHRIN	--	--	29,522	29,522	5.2%
BIFENTHRIN	--	--	16,447	16,447	2.9%
IMIDACLOPRID	--	--	16,447	16,447	2.9%
U.S. Total	--	--	**567,485**	**567,486**	**Column Total 97.4%**

Source: Proprietary third party data. Excluding seed treatment.

20.3.4 Stink Bugs

Stink bugs infest grain sorghum after flowering and feed upon the young, developing grain. Grain sorghum is most susceptible to stink bugs in the milk and soft dough stages. Once the grain is hard, susceptibility to stink bug damage is greatly reduced [1].

Chlorpyrifos was the second most-used active ingredient to control stink bug in grain sorghum, and was used on 22.6% of the pest acres treated for stink bug in 2012-2014. Chlorpyrifos is not labeled for stink bug control in grain sorghum, but may be used because it is registered to control other pests on the crop. Pyrethroids accounted for 74.0% of the pest acres treated for stink bug. Chlorpyrifos was the most-used non-pyrethroid insecticide. Effective non-pyrethroid insecticides, like chlorpyrifos, are needed to help manage resistance development.

Table 127. Leading Insecticide Active Ingredients Used to Control Stink Bug in Grain Sorghum – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
ZETA-CYPERMETHRIN	66,222	116,161	4,394	62,259	40.9%
CHLORPYRIFOS	42,315	60,976	--	34,430	22.6%
CYFLUTHRIN	68,761	--	--	22,920	15.1%
CYHALOTHRIN-LAMBDA	--	50,997	15,400	22,132	14.6%
U.S. Total	**192,230**	**244,148**	**19,794**	**152,057**	**Column Total 93.2%**

Source: Proprietary third party data. Excluding seed treatment.

20.4 Benefits of Chlorpyrifos in Grain Sorghum

- Effective control of the primary insect pests in grain sorghum including midge, head worm, yellow sugarcane aphid and stink bug as well as other economically important insect pests.
- Broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Significantly less disruptive to beneficial populations than the pyrethroids and does not flare aphids.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance. Pyrethroids (Group 3A) insecticides were used on an average of 62.7% of the active ingredient treated acres in grain sorghum in 2012-2014. Chlorpyrifos was the most-used non-pyrethroid insecticide in grain sorghum because of its effectiveness and broad spectrum of control. The availability of chlorpyrifos allows growers to rotate between different insecticide modes of action, which helps delay resistance development in all insecticides.
- Cost effective.

20.5 Chlorpyrifos Formulations, Rates, and Applications

The formulations listed for controlling insect pests in grain sorghum include Lorsban-4E (and other 4 lbs per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, Lorsban 15G (and other chlorpyrifos granular formulations), Cobalt, and Cobalt Advanced.

Location: Southern Plains (KS, OK, TX) and Southern states (AR, LO)

- Pests: midge
- Application Type: foliar
- Application Method: ground, air and chemigation
- Rate: 0.25 lb a.i./A
- Number of Applications: 1-3
- Season of Application: when 30-50% of the seed heads are in bloom

Location: Southern Plains (KS, OK, TX) and Southern states (AR, LO)

- Pests: yellow sugarcane aphid
- Application Type: foliar
- Application Method: ground, air and chemigation
- Rate: 0.25-0.5 lb a.i./A
- Number of Applications: 1-3
- Season of Application: seedling through preboot stage

Location: Southern Plains (KS, OK, TX) and Southern states (AR, LO)

- Pests: corn ear worm, webworm, armyworm
- Application Type: foliar
- Application Method: ground, air and chemigation
- Rate: webworm and armyworm (0.5-1.0 lb a.i./A), corn ear worm (1.0 lb a.i./A)
- Number of Applications: 1
- Season of Application: preboot through grain maturity

Table 128. Leading Chemical Treatments for Insect Control in Grain Sorghum.

Note: Information in the "Application, Use and Efficacy" section reflect the opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, Lorsban 15G, others	-Controls midge, head worm, yellow sugarcane aphid, stink bug, greenbug, chinch bug, cutworm, and other insect pests. -Fast knockdown of aphids. -Broad spectrum. -Group 1B MOA for resistance management. -Cost effective.
Chlorpyrifos + Gamma-Cyhalothrin/ Chlorpyrifos + Lambda-Cyhalothrin	Cobalt/ Cobalt Advanced	-Controls midge, head worm, yellow sugarcane aphid, stink bug, greenbug, chinch bug, cutworm and other insect pests. -Fast knockdown of aphids. -Broad spectrum. -Groups 1B and 3A MOA for resistance management. -Cost effective. -In general, this product will be effective against pyrethroid resistant populations of insects.
Cyfluthrin	Baythroid, others	-Controls midge, head worm, yellow sugarcane

Active Ingredient	Brand Names	Application, Use, and Efficacy
		aphid, stink bug and other insect pests. -Slow knockdown of aphid. -Broad spectrum. -Group 3A MOA.
Gamma-Cyhalothrin	Proaxis, others	-Controls midge, head worm, yellow sugarcane aphid, stink bug and other insect pests. -Slow knockdown of aphid. -Broad spectrum. -Group 3A MOA.
Lambda-Cyhalothrin	Warrior, Karate, others	-Controls midge, head worm, yellow sugarcane aphid, stink bug and other insect pests. -Broad spectrum. -Group 3A MOA.
Zeta-Cypermethrin	Mustang, others	-Controls midge, head worm, yellow sugarcane aphid, stink bug and other insect pests. -Slow knockdown of aphid. -Broad spectrum. -Group 3A MOA.

20.6 Non-Chemical Alternatives

The seasonal buildup of midge populations can be prevented by following planting practices on an area-wide basis that shorten the flowering period. Damaging midge infestations can be avoided by early, uniform planting. If the entire crop cannot be planted early, damaging midge infestations may be avoided in later, planted sorghum by delaying additional plantings by five to six weeks, and planting the all remaining fields within a few days.

20.7 References

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21. Soybeans

21.1 Overview

Processed soybeans are the largest source of protein feed and vegetable oil in the world. The U.S. is the world's leading soybean producer and exporter. Soybeans equal about 90% of total U.S. oilseed production, while cottonseed, sunflower seed, and peanuts account for the remainder [1].

An average of more than 79 million acres of soybeans have been grown annually in the U.S. in 2012-2014, with more than 84 million acres planted in 2014.

Table 129. U.S. Soybean Planted Acres 2012–2014.

Region[1]	Acres Planted (000)			
	2012	2013	2014	2012-2014 Average
Midwest	43,690	44,680	47,950	45,440
Plains	18,310	18,215	21,065	19,197
Atlantic	1,530	1,510	1,695	1,578
South	12,410	12,630	13,970	13,003
Total U.S.	**75,940**	**77,035**	**84,680**	**79,218**

Source: Proprietary third party data.
[1] USDA Farm Production Regions.

21.2 Chlorpyrifos Use

Total insecticide active ingredient treated acres averaged 22.85 million acres in 2012-2014, a decrease of 44% from the highs of the previous decade (40.8 million acres in 2008) when soybean aphid outbreaks first occurred in the Midwest and Plains states.

Chlorpyrifos was used on an average of 3.39 million acres of soybeans annually, and was the third most-used insecticide active ingredient in 2012-2014. Chlorpyrifos was widely used to control insect pests in soybeans due to its broad spectrum, fast knockdown of key pests, lack of flaring of mite populations, price, and value for use in insect resistance management programs. Pyrethroids accounted for 65% of the total active ingredient acres used on soybeans in 2012-2014. Chlorpyrifos was the most-used non-pyrethroid insecticide, and is important to the viability of long-term resistance management programs in soybeans.

Table 130. Leading Insecticide Active Ingredients Used in Soybeans – Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CYHALOTHRIN-LAMBDA	4,136,947	5,916,679	7,085,816	5,713,148	25%
BIFENTHRIN	4,046,115	3,143,003	3,571,743	3,586,954	16%
CHLORPYRIFOS	3,913,666	2,750,320	3,519,324	3,394,436	15%
CYFLUTHRIN	1,661,787	1,367,331	2,540,367	1,856,495	8%
ZETA-CYPERMETHRIN	964,998	1,395,369	1,468,395	1,276,254	6%
CYHALOTHRIN-GAMMA	888,558	1,980,625	784,802	1,217,995	5%
Total U.S.	**21,616,084**	**21,603,971**	**25,334,599**	**22,851,551**	**Column Total 74.6%**

Source: Proprietary third party data. Excluding seed treatments.

Growers used an average of 1,222,668 lb a.i. of chlorpyrifos annually to control insect pests in soybeans in 2012-2014, a 50% increase in average annual use from 2003-2007 (814,361 lb a.i.). The increase in chlorpyrifos use was primarily due its use to control soybean aphid.

Table 131. Chlorpyrifos Use in Soybeans – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	3,913,666	2,750,320	3,519,324	3,394,436
Lb a.i. Applied	1,435,982	1,073,324	1,158,698	1,222,668

Source: Proprietary third party data.

21.2.1 Midwest and Plains Regions

The Midwest (Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin) and Plains (Kansas, Nebraska, North Dakota, Oklahoma, South Dakota and Texas) regions represent over 80% of total soybean acres grown in the U.S. Of the 84.7 million soybean acres grown in 2014 across the U.S., 64.6 million of those acres were grown in the Midwest and Plains region. The top six producing states, including Iowa and Illinois (tied with the most soybean acres), Minnesota, North Dakota, Missouri and Indiana, account for 53% of 2014 planted acres.

Chlorpyrifos and lambda-cyhalothrin were the most widely used insecticides in the Midwest and Plains regions to control insects in soybeans. Chlorpyrifos was used to treat an average of 3.35 million acres annually, 25% of the total active ingredient acres in the

Midwest and Plains regions in 2012-2014. Use of chlorpyrifos in this region is surpassed only by lambda-cyhalothrin.

Table 132. Leading Insecticide Active Ingredients Used in Midwest and Plains Region Soybeans –Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CYHALOTHRIN-LAMBDA	2,499,919	4,390,377	5,036,470	3,975,589	29.7%
CHLORPYRIFOS	3,895,468	2,706,415	3,446,532	3,349,472	25.0%
BIFENTHRIN	1,586,592	1,691,003	1,888,725	1,722,107	12.9%
CYHALOTHRIN-GAMMA	696,351	1,070,527	692,356	819,745	6.1%
ZETA-CYPERMETHRIN	483,534	846,841	1,119,187	816,521	6.1%
CYFLUTHRIN	320,946	629,126	899,519	616,530	4.6%
Total Midwest and Plains Regions	**10,923,564**	**13,371,578**	**15,840,819**	**13,378,654**	**Column Total 84.5%**

Source: Proprietary third party data. Excluding seed treatments.

21.3 <u>Target Pests</u>

"Soybeans typically harbor an incredible diversity of insects that feed on the plants from the time they start to crack the soil until the last leaf has dropped in the late summer. And somewhere between these two extremes, insect and spider mite populations occasionally build up to economically damaging populations. When this happens, often the most effective pest management tactic for most growers and crop managers is to apply a foliar insecticide to reduce the population" [2].

Chlorpyrifos has a broad spectrum, and is effective in treating a number of insect pests in soybeans including soybean aphid, bean leaf beetle, caterpillars, grasshoppers, leafhopper, two spotted spider mites, and others. Other primary insecticide products used in the market have a narrower pest spectrum compared to chlorpyrifos' broad pest spectrum.

21.3.1 Soybean Aphid

The number one pest in the Midwest and Plains is the soybean aphid. Soybean aphids feeding on soybean crops can result in a reduction in photosynthetic capacity as well as cause leaf curling and stunted plant growth. Infestations of soybean aphid spread rapidly since it was first detected in Wisconsin in 2000. By 2002, soybean aphid presence was reported in 20 states across the Plains and into the Northeast and South. Since 2000, heavy infestations of the soybean aphid have caused economic yield losses up to 45% in some untreated fields [3]. Chlorpyrifos has been used in the U.S. since 2000 to control soybean aphid [4].

Of the 25.3 million total active ingredient acres treated in 2014, 37.7% (9.5 million active ingredient acres) were treated to control soybean aphids, far exceeding insecticide use to control other insect pests.

Table 133. Top Insect Pests Treated in Soybeans – Pest Acres 2014.

Insect	Pest Treated 2014	% of Total a.i. Treated Acres 2014
APHID, SOYBEAN	9,548,340	37.7%
BEETLE, BEAN LEAF	3,637,594	14.4%
BUG, STINK	3,579,175	14.1%
GRASSHOPPER	2,615,386	10.3%
WORM, CORN EAR	2,317,269	9.1%
BUG, GREEN STINK	2,111,203	8.3%
BEETLE, JAPANESE	2,080,633	8.2%
Total U.S.	**42,001,839**	**Column Total 102.2%**

Source: Proprietary third party data. Excluding seed treatments.

Nearly 97 % of the soybean aphid treated acres occur in the Midwest and Plains regions. Of the 15.8 million total active ingredient acres treated in the Midwest and Plains region acres in 2014, 58.2% (9.2 million active ingredient treated acres) were used to control soybean aphid. Chlorpyrifos and lambda-cyhalothrin, accounted for 52.1% and 79.7% of the active ingredient acres treated for soybean aphid in the Midwest and Plains regions, respectively (data not presented).

Table 134. Top Insect Pests Treated in Soybeans in the Midwest and Plains States – Pest Acres 2014.

Insect	Pest Treated 2014	% of Total a.i. Treated Acres 2014
APHID, SOYBEAN	9,221,464	58.2%
BEETLE, BEAN LEAF	2,142,487	13.5%
GRASSHOPPER	2,023,855	12.8%
BUG, STINK	1,451,192	9.2%
BEETLE, JAPANESE	1,350,251	8.5%
MITE, SPIDER	990,189	6.3%
Total U.S.	**22,798,736**	**Column Total 108.5%**

Source: Proprietary third party data. Excluding seed treatments.

21.3.2 Bean Leaf Beetle

The bean leaf beetle is also one of the most widespread soybean pests in the U.S. The resulting damage from this pest is loss of seed weight and quality. These beetles can also cause breakage and complete pod loss. Grain value is discounted when 2% damaged seed is exceeded. Chlorpyrifos is the second most-used insecticide active ingredient for bean leaf beetle control.

21.3.3 Two Spotted Spider Mite

The two spotted spider mite (TSSM) is a widely distributed soybean pest, and is also common in many other field crops. When environmental conditions are hot and dry, spider mites multiply rapidly and become a major pest of soybeans. Environmental conditions do not become favorable for the mite until mid summer to late summer. TSSMs have 20+ generations per year and feed on the underside of foliage with sucking mouth parts, and are very destructive when abundant. Feeding causes discoloration and premature leaf drop, resulting in decreased chlorophyll and transpiration and irreversible damage. Hot and dry conditions favor mites, and TSSMs thrive on plants that are under stress. Severely infested fields appear discolored, lose leaves, have reduced plant vigor, and individual plants may die. Yield reductions may exceed 33% in severely infested fields [5].

Spraying for soybean aphid with certain insecticides can aggravate spider mite problems. Many of the insecticides labeled against soybean aphid are either ineffectual against spidermites, or may even aggravate the situation. Although a few of the pyrethroids are labeled for TSSM control, they are listed as "suppression only" and may even aggravate the situation because these insecticides remove predatory mites and insects. They also may stimulate more rapid TSSM reproduction [5]. Bifenthrin is the only pyrethroid that controls TSSM.

Currently only a few insecticides are available that control mites in soybeans: chlorpyrifos, dimethoate, and bifenthrin [6]. Chlorpyrifos and dimethoate are preferred for the first application. If a second treatment is necessary, universities recommend re-spraying a different product, and with a different mode of action to prevent resistance development. Pyrethroids are often used for the second application although, with the exception of bifenthrin, they are generally not as effective.

The low rates of chlorpyrifos (less than 0.5 lb a.i./A) applied to control soybeans aphids are also highly effective against TSSM and are significantly less disruptive to beneficial populations than the pyrethroids. Chlorpyrifos offers a Group 1B mode of action to manage resistance development, and provides an excellent rotation partner to extend the life of all products. Revoking the registration of chlorpyrifos on soybeans would leave growers with fewer alternatives to control TSSM and fewer rotational partners for integrated resistance management programs. If chlorpyrifos were no longer available, pyrethroid use would increase, which may result in the flaring of spider mites, and lead to even more insecticide required per acre over the course of the season.

21.4 Integrated Resistance Management

Aphids are notorious for developing resistance to insecticides. Growers can delay resistance development by minimizing exposure to insecticides, and only treating when populations exceed the economic threshold. Also, rotating modes of action will prolong the effectiveness of products. The pyrethroids accounted for over 65% of the active ingredient acres treated for soybeans aphid control in 2012-2014. All universities strongly recommend rotating modes of action, particularly if more than one application including seed treatment is made during a single growing season. Since the neonicotinoids (Group 4A) are typically applied as a seed treatment, only organophosphate (Group 1B) and pyrethroids (Group 3A) are recommended for use later in the season [7]. Chlorpyrifos is highly effective against soybean aphid, and offers a Group 1B mode of action to help manage resistance development. It provides an excellent rotation partner to extend the life of all products.

21.5 Cost of Treatment

The national average cost of chlorpyrifos in soybeans was $4.07 per acre in 2014, which was equal to both the average cost of lambda-cyhalothrin and the average cost of all insecticide alternatives used in soybeans. The national average cost of insecticides differed from average costs in the Midwest and Plains regions. The cost of chlorpyrifos was $3.41 per acre in the Midwest and Plains regions in 2014, which was 9% less than the average cost of all alternatives ($3.74 per acre) and 24% less than the average cost of lambda-cyhalothrin ($4.47 per acre). Based on the average cost of lambda-cyhalothrin, growers in this region would have spent $2.5 million more in 2014 had chlorpyrifos not been available for use on soybeans. This does not take into account that some of the alternative products may not control all pests present at the time of application, which would result in additional insecticide use and cost.

21.6 Benefits of Chlorpyrifos in Soybeans

- Chlorpyrifos is the leading non-pyrethroid insecticide active ingredient and second most-used insecticide to control soybean aphid and other insect pests.
- Effective control of the primary insect pests in soybeans including soybean aphid, bean leaf beetle, grasshoppers, spider mites, and stink bug as well as other economically important insect pests.
- Fast knockdown of aphids – superior aphid control compared to lambda-cyhalothrin and other pyrethroids, which provide slower control and may allow aphid populations to rebuild following treatment.
- Provides broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Significantly less disruptive to beneficial populations than the pyrethroids and does not flare mites.

- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance. Pyrethroid (Group 3A) insecticides were used on an average of 65% of the active ingredient treated acres in soybeans in 2012-2014. Chlorpyrifos was the most-used non-pyrethroid insecticide in soybeans because of its effectiveness and broad spectrum of control. The availability of chlorpyrifos allows growers to rotate between different insecticide modes of action, which helps delay resistance development in all insecticides.
- Cost effective.

21.7 Chlorpyrifos Formulations, Rates, and Applications

Current chlorpyrifos formulations listed for treating soybeans include Lorsban 4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, Lorsban 15G (and other chlorpyrifos granular formulations), Cobalt, and Cobalt Advanced.

For foliar application, chlorpyrifos is most commonly applied as a broadcast spray using aerial or ground equipment.

Location: IA, IL, IN, OH, MN, WI, SD, MO, NE

- Pests: soybean aphid, bean leaf beetle, spider mite
- Application Type: foliar
- Application Method: broadcast aerial or ground
- Rate: 0.25-0.5 lb a.i./A
- Number of Applications: 1
- Season of Application: July/August

Location: AL, GA

- Pests: stink bug, armyworm, European corn borer
- Application Type: foliar
- Application Method: broadcast aerial and ground
- Rate: 0.5-1.0 lb a.i./A
- Number of Applications: 1-3
- Season of Application: May-August

Table 135. Leading Chemical Treatments for Insect Control in Soybeans

Note: Information in the "Benefits, Application, Use and Efficacy" section reflect opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, Lorsban 15G,	-Controls soybean aphid, bean leaf beetle, grasshoppers, spider mites, stink bug and other insect pests. -Controls TSSM -Broad spectrum. -Fast knockdown.

Active Ingredient	Brand Names	Application, Use, and Efficacy
	others	-Group 1B MOA for resistance management -Cost-effective
Chlorpyrifos + Gamma-Cyhalothrin/ Chlorpyrifos + Lambda-Cyhalothrin	Cobalt/ Cobalt Advanced	-Controls soybean aphid, bean leaf beetle, grasshoppers, spider mites, stink bug and other insect pests. -Controls TSSM -Broad spectrum. -Fast knockdown. -Groups 1B and 3 MOA for resistance management -Cost-effective -In general, this product will be effective against pyrethroid resistant populations of insects.
Acephate	Orthene, others	-Higher rate than most. -Less effective. -Group 1B MOA.
Bifenthrin	Brigade, Capture, others	-Good control of soybeans aphid. -Controls TSSM. -Broad spectrum. -Slow knockdown. -Poor stand-alone alternative when pyrethroid-resistant insects are present. -Group 3A MOA.
Cyfluthrin	Baythroid, others	-Less effective on soybean aphid. -May flare TSSM. -Broad spectrum. -Poor stand-alone alternative when pyrethroid-resistant insects are present. -Group 3A MOA.
Cyfluthrin + Imidacloprid	Leverage	-Good control of soybean aphid. -Broad spectrum. -Not recommended if a Group 4A MOA seed treatment was used. -Groups 3 and 4B MOA.
Esfenvalerate	Asana	-Less effective on soybean aphid. -May flare TSSM. -Broad spectrum. -Poor stand-alone alternative when pyrethroid-resistant insects are present. -Group 3A MOA.
Gamma-Cyhalothrin	Proaxis, others	-Good control of soybean aphid. -May flare TSSM. -Broad spectrum. -Slow knockdown. -Poor stand-alone alternative when pyrethroid-resistant insects are present. -Group 3A MOA.
Lambda-Cyhalothrin	Warrior, Karate, others	-Provides the most consistent control of soybean aphid among the pyrethroids.

Active Ingredient	Brand Names	Application, Use, and Efficacy
		-Slow knockdown but good residual -Broad spectrum. -May flare TSSM. -Poor stand-alone alternative when pyrethroid-resistant insects are present. -Group 3A MOA.
Lambda-cyhalothrin + Thiamethoxam	Endigo	-Good control of soybean aphid. -Broad spectrum. -Not recommended if a Group 4A MOA seed treatment was used. -Groups 3 and 4B MOA.
Zeta-Cypermethrin	Mustang, others	-Good control of soybean aphid. -May flare TSSM. -Broad spectrum. -Slow knockdown. -Poor stand-alone alternative when pyrethroid-resistant insects are present. -Group 3A MOA.

21.8 Non-Chemical Alternatives

Several naturally occurring organisms prey on and suppress soybean aphid populations; however, no biological agents are commercially available. Soybean aphids can be heavily preyed upon by a large assortment of lady beetles (*Coleoptera: Coccinellidae*) and hymenopteran parasitoids. In addition, fungal pathogens can help suppress populations. Universities do not recommend using insecticides when small populations of soybean aphids are first found in a field because natural enemies may help suppress low aphid populations. However, beneficial populations have not provided adequate suppression when aphid populations are high.

Soybean aphid-resistant varieties have been developed that contain the Rag1 gene, which slows the rate at which aphid populations increase. The resistant plants will not be aphid-free, but will have fewer aphids than susceptible varieties. Soon after their development, populations of aphids were identified that would tolerate the Rag1 resistance due to the wide range of genetic diversity in the soybean aphid population [8]. As a result, Rag1 aphid-resistant varieties have received limited use.

21.9 Grower Perspective

In late 2007, the EPA asked for public comments on issues related to the agricultural use of chlorpyrifos. Following is an excerpt from a state grower organization that responded to the EPA's request for input by explaining why they considered chlorpyrifos essential for protecting their crops. Submissions to the docket are public information and have been posted by the EPA at www.regulations.gov, docket number EPA-HQ-OPP-2007-

1005. Growers also commented during public comment periods in 2011 (EPA-HQ-OPP-2008-0850-0025) and 2015 (EPA-HQ-OPP-0850-0224).

"Chlorpyrifos is an extremely important insecticide for soybean production in Minnesota, as well as most of the upper Midwest. Chlorpyrifos effectively controls two very significant pests in soybean production – spider mites and soybean aphids. Infestations of spider mites can be sporadic [and when they] do occur, yield reductions of greater than 50% can result. Based on University of Minnesota research, chlorpyrifos is the product of choice for controlling spider mites in soybeans.... Chlorpyrifos is one of only two types of products that have proven to provide effective control of soybean aphids. The other products are synthetic pyrethroids...and their use has sometimes resulted in the need to make supplemental applications of chlorpyrifos to control spider mites." – Minnesota Soybean Growers Association

21.10**References**

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22. Strawberries

22.1 Overview

An average of 55,803 acres of strawberries were grown annually in the U.S. in 2012-2014. Over 71% of the commercial strawberry acreage was grown in California and 17% was grown in Florida.

Table 136. U.S. Strawberry Production – Acres Grown 2012-2014.

State	Acres Grown			
	2012	2013	2014	2012-2014 Average
CALIFORNIA	38,500	38,500	41,500	39,500
FLORIDA	8,900	8,900	11,000	96,00
OREGON	2,200	2,200	2,000	2,133
NEW YORK	1,600	1,600	1,200	1,467
WASHINGTON	1,500	1,500	1,300	1,433
PENNSYLVANIA	920	920	820	887
MICHIGAN	750	750	850	783
U.S. Total	**54,370**	**54,370**	**58,670**	**55,803**

Source: Proprietary third party data.

22.2 Chlorpyrifos Use

Although chlorpyrifos use in strawberries only averaged 1.0% of all active ingredient acres treated on this crop in 2012-2014, it is an important tool in the U.S. strawberry production systems. Growers used an average of 8,277 lb a.i. of chlorpyrifos annually to control insect pests in strawberries in 2012-2014, an 18% decrease from average annual use in 2003-2007 (10,043 lb a.i.). Chlorpyrifos was primarily used for control of cutworms, armyworms, strawberry bud weevil and garden symphylan in strawberries. Maintaining the availability of chlorpyrifos in the strawberry insecticide complex is important for the control of these pests, and the viability of long-term resistance management programs.

Table 137. Chlorpyrifos Use in Strawberries – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	13,324	9,855	1,193	8,124
Lbs a.i. Applied	13,605	9,953	1,273	8,277

Source: Proprietary third party data.

22.3 <u>Target Pests</u>

Lygus bug, mites, thrip, aphid, armyworm and miscellaneous worms were the top target pests in strawberries, and accounted for 97.6% of the total active ingredient acres in 2012-2014. Cutworms, strawberry bud weevil, and garden symphylan also cause significant losses in strawberries as described below. Chlorpyrifos provides broad spectrum control of a number of insect pests in strawberries, and was among the leading active ingredients used to control beet armyworm, cutworm and garden symphylan.

Table 138. Top Insect Pests in Strawberries – Acres Treated 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
BUG, LYGUS	201,178	276,661	342,116	273,318	34.5%
MITE, 2-SPOTTED	112,534	156,056	117,324	128,638	16.2%
THRIP	100,041	112,030	146,371	119,481	15.1%
APHID	37,812	103,209	116,158	85,726	10.8%
ARMYWORM	59,004	77,785	117,362	84,717	10.7%
WORM	68,308	76,748	100,825	81,960	10.3%
U.S. Total	**869,824**	**1,075,608**	**1,291,430**	**1078954**	**Column Total 97.6%**

Source: Proprietary third party data.

22.3.1 Beet Armyworm

Young beet armyworm larvae feed on foliage and crowns before attacking berries. The greatest damage can occur if larvae feed in the crowns of newly transplanted strawberry plants. Feeding at this time can kill the young transplants. Damage also can occur to summer-planted strawberries. Fall populations of armyworm moths will often fly into strawberry fields to lay eggs. Newly hatched armyworms feed on foliage, skeletonizing the upper or lower leaf surfaces next to their egg mass. Larger armyworms feed directly into the berries; smaller armyworms will often feed on the shoulder of the berry beneath the calyx sepals [1].

22.3.2 Cutworm

Early season damage by newly hatched cutworms generally appears as small, webless perforations in the newly expanding crown leaves. As larvae grow, they begin their characteristic stem cutting, along with chewing larger, irregular holes in the foliage. Serious damage can occur to the plant crown when the central growing point of young plants is eaten. Damage often occurs along the edges of fields adjacent to backyards or to more favored crops such as lettuce or beans. Most damage occurs in the fall and spring, with the fall attack being more destructive. During harvest, cutworms can cause rather pronounced holes in the fruit. Damaged berries tend to be concentrated in localized areas of one to several plants around each active cutworm [2].

Chlorpyrifos was the third most-used insecticide active ingredient to control armyworm and cutworm in strawberry, and was used on 8.8% of the pest acres treated for armyworm, beet armyworm and cutworm in 2012-2014. Chlorpyrifos is not labeled for armyworm, beet armyworm or cutworm control in strawberry, but may be used because it is registered to control other pests on the crop.

Table 139. Leading Insecticide Active Ingredients Used to Control Armyworm and Cutworm in Strawberries – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
BACILLUS THURINGIENSIS	20,668	38,095	58,506	39,090	36.9%
SPINETORAM	12,019	3,197	25,207	13,475	12.7%
CHLORPYRIFOS	21,357	6,583	--	9,313	8.8%
METHOXYFENOZIDE	15,104	8,266	2,467	8,612	8.1%
BIFENTHRIN	3,195	9,004	12,707	8,302	7.8%
CHLORANTRANILIPROLE	1,657	12,046	9,784	7,829	7.4%
U.S. Total	**89,029**	**89,112**	**139,934**	**106,025**	**Column Total 81.7%**

Source: Proprietary third party data.

22.3.3 Garden Symphylan

Garden symphylans damage plants by feeding on roots, thus retarding plant growth. They are usually only a problem in strawberry fields that were not fumigated, or if the fumigation was ineffective. Chlorpyrifos was used on all strawberry acres that were treated for garden symphylans in 2012-2014. Maintaining the availability of chlorpyrifos in the strawberry is important because there are few alternatives available to control this pest.

22.4 Benefits of Chlorpyrifos in Strawberries

- Chlorpyrifos is the insecticide most used for garden symphylan control – few alternatives are available for control of this pest.
- Effective control of beet armyworm, cutworms, garden symphylan, strawberry bud weevil and other economically important insect pests. Chlorpyrifos is not labeled for beet armyworm or cutworm control in strawberry, but may be used because it is registered to control other pests on the crop.

- Provides broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.
- Cost effective.

22.5 Chlorpyrifos Formulations, Rates, and Applications

The formulations listed for controlling insect pests in grain sorghum include Lorsban-4E (and other 4 lbs per gallon EC formulations of chlorpyrifos), Lorsban Advanced and Lorsban 75WG.

Location: CA, FL, MI, NY, OR, PA, WA

- Pests: strawberry bud weevil, strawberry crown moth (not included on label – beet armyworm, cutworm)
- Application Type: foliar
- Application Method: ground
- Rate: 1.0 lb a.i./A
- Number of Applications: 1-3
- Season of Application: spring, summer or fall. Do not apply after berries start to form or when berries are present.

Table 140. Leading Chemical Treatments for Insect Control in Strawberry.

Note: Information in the "Application, Use and Efficacy" section reflect opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, others	-Control of strawberry bud weevil and garden symphylan, and although not labeled insects, used to control beet armyworm, cutworm, stink bug and other insect pests. -Broad spectrum. -Group 1B MOA for resistance management. -Cost effective
Bacillus thuringiensis (Bt)	Several	-Controls beet armyworm and cutworm. -Treat when armyworms and cutworms are still small. To be effective, must be applied no later than the 2nd instar beet armyworm. -Approved for certified organic crop use. -Group 11A MOA.
Methoxyfenozide	Intrepid	-Controls armyworm, beet armyworm and corn ear worm control -Suppresses cutworm. -Insect growth regulator. -Group 18 MOA.
Spinetoram	Radiant	-Controls armyworm, beet armyworm, leafroller and thrip.

Active Ingredient	Brand Names	Application, Use, and Efficacy
		-Group 5 MOA.
Spinosad	Entrust	-Controls armyworm, beet armyworm, leafroller and thrip. -Approved for certified organic crop use. -Group 5 MOA.

22.6 Non-Chemical Alternatives

Good weed control helps minimize armyworm and cutworm populations by eliminating egg laying sites. Annual planting and thorough pruning of second-year strawberry plantings reduces survival of overwintering cutworm larvae.

Continuous flooding for three weeks in the summer helps reduce garden symphylan infestations. Disking in a crop of sorghum has been reported to reduce garden symphylan infestations in other crops.

22.7 References

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23. Sugarbeets

23.1 Overview

Over 1.19 million acres of sugarbeets were grown annually in the U.S. in 2012-2014. Minnesota and Michigan account for nearly 52% of the U.S. sugar beet crop. Minnesota is the largest sugar beet producing state with 466,669 acres planted, followed by North Dakota with nearly 222,331 acres. Sucrose from sugar beets is the principal use for sugar beets in the U.S. Sugar beets have gained a greater share of U.S. sugar production over the past decade. Sugar beet byproducts include beet pulp, sold for animal feed, molasses and ethanol.

Table 141. U.S. Sugarbeet Production – Acres Planted 2012-2014.

Region[1]	State	Acres Planted			
		2012	2013	2014	2012-2014 Average
Midwest	MINNESOTA	489,996	470,009	440,000	466,669
	MICHIGAN	153,999	152,001	151,000	152,333
West	IDAHO	183,001	175,001	171,000	176,334
	MONTANA	46,501	43,398	44,900	44,933
	WYOMING	31,801	29,900	30,200	30,634
	COLORADO	31,201	26,799	29,400	29,133
	CALIFORNIA	25,000	24,499	24,500	24,667
Plains and Midwest	NORTH DAKOTA	219,998	229,995	217,000	222,331
	NEBRASKA	51,000	45,999	48,000	48,333
U.S. Total		**1,232,497**	**1,197,602**	**1,156,000**	**1,195,366**

Source: Proprietary third party data.
[1] USDA Farm Production Regions.

23.2 Chlorpyrifos Use

Chlorpyrifos and zeta-cypermethrin were the two most-used active ingredients to control insect pests in sugarbeets.

Table 142. Leading Insecticide Active Ingredients Used in Sugarbeets – Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
ZETA-CYPERMETHRIN	328,962	206,050	282,531	272,515	31.9%
CHLORPYRIFOS	274,580	314,796	159,636	249,670	29.2%
TERBUFOS	185,360	184,997	152,543	174,300	20.4%
ESFENVALERATE	80,165	93,372	60,801	78,113	9.2%
METHOXYFENOZIDE	32,319	--	16,332	16,217	1.9%
U.S. Total	**997,692**	**850,734**	**712,303**	**853,576**	Column Total **92.6%**

Source: Proprietary third party data. Excluding seed treatments.

Growers used an average of 181,941 lb a.i. of chlorpyrifos annually to control insect pests in sugarbeets in 2012-2014, a 32% increase in average annual use from 2003-2007 (138,020 lb a.i.). Four states, Minnesota, California, Idaho, and North Dakota accounted for 94.8% of the chlorpyrifos active ingredient treated acres. Idaho leads in chlorpyrifos use and accounted for 53% of chlorpyrifos active ingredient treated acres.

Table 143. Chlorpyrifos Use in Sugarbeets – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	274,580	314,796	159,636	249,670
Lb a.i. Applied	192,546	240,270	113,008	181,941

Source: Proprietary third party data.

23.3 Target Pests

The top insect pests in sugar beets were root maggot, cutworm, leafminer, wireworm springtail, armyworm, flea beetle and bean aphid. An average of 31.2% of the active ingredient treated acres were used to control root maggot, 19.8% were used to control cutworm, 17.2% were used to control leafminer, and 17.2% were used to control wireworms in 2012-2014.

Table 144. Top Insect Pests in Sugarbeets – Pest Acres 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CUTWORM	188,220	138,937	179,510	168,889	19.8%
MAGGOT, ROOT	128,385	178,516	182,812	163,238	19.1%
LEAFMINER	211,160	188,827	39,977	146,655	17.2%
WIREWORM	132,114	141,741	166,009	146,622	17.2%
MAGGOT, SUGARBEET ROOT	131,764	118,302	60,782	103,616	12.1%
SPRINGTAIL	126,836	65,647	50,697	81,060	9.5%
ARMYWORM	37,346	46,175	43,545	42,355	5.0%
BEETLE, FLEA	34,415	56,994	25,070	38,826	4.5%
APHID, BEAN	10,103	78,438	23,091	37,211	4.4%
U.S. Total	**1,474,354**	**1,261,902**	**1,038,117**	**1,258,124**	**Column Total 108.8%**

Source: Proprietary third party data. Excluding seed treatments.

At-plant soil applications of a granular chlorpyrifos formulation are effective for controlling sugar beet root maggot and cutworms. Post-emergence applications of either a liquid or a granular chlorpyrifos formulation are highly effective for controlling sugarbeet root maggot. Foliar applications of a liquid chlorpyrifos formulation are effectively used to control armyworms, cutworms, leafminers, grasshoppers, Lygus plant bug (tarnish plant bug), and aphids.

23.3.1 Root Maggot

Root maggot larvae cause damage, reduce yield tonnage, and lower root sucrose content by scraping the root surface with rasping mouthhooks. Seedlings are most susceptible to injury because maggot feeding can cut the root and kill the plant. The probability of stand loss is greatest for late planted sugar beets that are in the seedling stages when flies reach seasonal peaks.

When infestations are severe, lesions may cover the entire root surface. Feeding on the root tip causes the taproot to fork and branch. Damaged plants wilt during May and June, especially between irrigations. Losses are compounded when root-rot pathogens invade maggot feeding wounds. In fields with histories of root rot, even minor root maggot infestations can combine with soil pathogens and eliminate the stand [1].

Chlorpyrifos and terbufos were the leading active ingredients used to control root maggot.

Table 145. Leading Insecticide Active Ingredients Used to Control Root Maggot in Sugarbeets – Pest Acres 2012-2014.

Insecticide	Acres Treated				% of Total Peat Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
TERBUFOS	93,397	141,487	126,570	120,485	41.1%
CHLORPYRIFOS	124,316	125,433	64,049	104,599	35.7%
ZETA-CYPERMETHRIN	67,626	40,647	57,885	55,386	18.9%
PHORATE	14,542	3,876	4,680	7,699	2.6%
ESFENVALERATE	303	4,531	9,559	4,798	1.6%
U.S. Total	**300,184**	**315,974**	**262,744**	**292967**	**100.0%**

Source: Proprietary third party data. Excluding seed treatments.

23.3.2 Cutworm, Leafminer and Armyworm

Cutworms feed at night just below the soil surface during dry periods. Typical damage will be areas of wilted or dead beets in the fields. Large areas can be damaged within a beet field overnight if cutworm populations are high [2].

Armyworms skeletonize leaves, leaving the veins largely intact. In severe infestations as food becomes scarce, they will consume the veins, petioles, and will even feed on the exposed portions of the beet root. Infestations can occur very early in the crop, particularly during cotyledon stages of fall-planted beets. Larvae can consume the entire plant and cause reductions in stand. During mid-season, severe defoliation can cause reductions in root size. During the latter parts of the season, regrowth which occurs to compensate for skeletonized leaves can reduce the percentage of sucrose in the harvested root [3].

Both leafminer larvae and adults cause damage to plants. Larval (maggot) feeding results in slender, winding trails on the leaves, which form large, white blotches when mining becomes severe. Adult flies damage plants by carving small pits on the leaf surface with their ovipositors, and feeding on plant exudates. There may be as many as 100 feeding punctures on a single leaf. Around 5% of these punctures may contain actively feeding larvae [4].

Chlorpyrifos and zeta-cypermethrin were the leading insecticides used to control cutworm, leafminer and armyworm in sugarbeets.

Table 146. Leading Insecticide Active Ingredients Used to Control Cutworm, Leafminer and Armyworm in Sugarbeets – Acres Treated 2012–2014.

Insecticide	Acres Treated				% of Total Peat Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
ZETA-CYPERMETHRIN	174,911	88,465	134,427	132,601	37.0%
CHLORPYRIFOS	145,013	196,925	39,957	127,298	35.6%
ESFENVALERATE	67,238	52,022	33,534	50,931	14.2%
TERBUFOS	35,326	15,912	16,477	22,572	6.3%
METHOXYFENOZIDE	--	--	32,664	10,888	3.0%
U.S. Total	**436,726**	**373,939**	**263,032**	**357,899**	**Column Total 96.2%**

Source: Proprietary third party data. Excluding seed treatments.

23.4 Benefits of Chlorpyrifos in Sugarbeets

Chlorpyrifos has been an integral component in sugar beet pest management programs for decades due to its efficacy, and broad spectrum pest control using conventional agricultural application equipment. Chlorpyrifos offers broad spectrum control of numerous pest species including aphids, root maggot, leafminer, and worms. In contrast to esfenvalerate and zeta-cypermethrin, chlorpyrifos is labeled for sugar beet root maggot control; a serious pest of sugar beet production.

Sugar beet growers need chlorpyrifos as an alternative product for foliar treatments in heavy maggot pressures. Chlorpyrifos can be used as a foliar (post) treatment following an at-plant application of terbufos, the leading at-plant material for sugar beet root maggot control. Chlorpyrifos applied as a foliar treatment controls adult sugar beet root maggot flies, and also provides some soil activity for active maggots. Chlorpyrifos has a "CAUTION" signal word and is less hazardous material to handle than terbufos which has a "DANGER POISON" signal word.

23.5 Chlorpyrifos Formulations, Rates, and Applications

Formulations listed for controlling insect pests in sugar beets include Lorsban 15G, (and other chlorpyrifos granular formulations), Lorsban-4E, (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, and Lorsban 75WG.

Location: Pacific Northwest

- Pests: worm pests, flea beetles, aphid
- Application Type: ground
- Application Method: broadcast directed
- Rate: 0.25-1.0 lb a.i./A
- Number and season of Applications: 1, Spring/Summer

Location: WA, OR, ID

- Pests: black bean aphid, cutworm, sugarbeet root maggot
- Application Type: aerial and ground
- Application Method: post-emergence/broadcast
- Rate: 1.0 lb a.i./A
- Number of Applications: 1
- Timing: maggot/cutworm April, May; Aphid July-September

Location: Midwest – ND, MN

- Product: Lorsban 15G
- Pest: root maggot, cutworms, wireworms
- Application Type: ground
- Application Method: at-plant
- Rate: 0.75-1.5 lb a.i./A
- Number of Applications: 1
- Timing of Applications: at-plant

Location: Midwest – ND, MN

- Product: Lorsban 15G
- Pest: root maggot, cutworms, wireworms
- Application Type: ground
- Application Method: directed
- Rate: 1.0-1.5 lb a.i./A
- Number of Applications: 1
- Timing of Applications: post

Location: Midwest – ND, MN

- Product: Lorsban-4E, Lorsban Advanced, Cobalt, etc.
- Pest: leaf miners, spider mites
- Application Type: ground, air, chemigation
- Application Method: broadcast
- Rate: 0.5 lb a.i./A
- Number of Applications: 1
- Timing of Applications: post

Location: Midwest – ND, MN

- Product: Lorsban-4E, Lorsban Advanced, Lorsban 75WG
- Pest: fall armyworm, yellow stripped armyworm, webworms
- Application Type: ground, air, chemigation
- Application Method: broadcast
- Rate: 0.5-1.0 lb a.i./A

- Number of Applications: 1
- Timing of Applications: post

Location: Midwest – ND, MN

- Product: Lorsban-4E, Lorsban Advanced, Lorsban 75WG
- Pest: beet armyworm
- Application Type: ground, air, chemigation
- Application Method: broadcast
- Rate: 0.75-1.0 lb a.i./A
- Number of Applications: 1
- Timing of Applications: post

Location: Midwest – ND, MN

- Product: Lorsban-4E, Lorsban Advanced, Lorsban 75WG
- Pest: flea beetle adults, sugarbeet root maggot larvae
- Application Type: ground, air, chemigation
- Application Method: broadcast
- Rate: 1.0 lb a.i./A
- Number of Applications: 1
- Timing of Applications: post

Location: Midwest – ND, MN

- Product: Lorsban-4E, Lorsban Advanced, Lorsban 75WG
- Pest: sugarbeet root maggot adults
- Application Type: ground, air, chemigation
- Application Method: broadcast
- Rate: 0.25-0.5 lb a.i./A
- Number of Applications: 1
- Timing of Applications: post

Location: Midwest – ND, MN

- Product: Lorsban-4E, Lorsban Advanced, Lorsban 75WG
- Pest: sugarbeet root maggot larvae
- Application Type: ground
- Application Method: band
- Rate: 0.3325-0.5 lb a.i./A
- Number of Applications: 1
- Timing of Applications: post

Table 147. Leading Chemical Treatments for Insect Control in Sugarbeets.

Note: Information in the "Benefits, Application, Use and Efficacy" section reflect opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, Lorsban 15G, others	-Broad spectrum control of pests, including sugar beet maggot control. -Superior control of leafminer and Lygus -Flexible application type and method. -Broad spectrum. -Group 1B MOA for resistance management. -Cost effective.
Esfenvalerate	Asana	-Controls armyworm, cutworm, leafminer, Lygus bug. -Foliar, at-plant. -Root maggot control is for adults only as a foliar spray. -Group 3A MOA.
Methomyl	Lannate	-Good activity against armyworm. -"Danger" signal word. -Group 1A MOA.
Methoxyfenozide	Intrepid	-Good activity against armyworm. -Group 18 MOA.
Phorate	Imidan	-Controls root maggot. -Post-emergence treatment. -One application/year. -"Danger" signal word. -Group 1B MOA.
Terbufos	Counter	-Effective control of Lygus bug and aphid. -At-plant. -Nematicidal benefit. - "Danger" signal word. -Group 1B MOA.
Zeta-Cypermethrin	Mustang Max	-Armyworm, cutworm, leafminer, Lygus bug -Foliar, at-plant. -Root maggot control is for adults only as a foliar spray. -Group 3A MOA.

23.6 Non-Chemical Alternatives

There are currently no practical non-chemical control alternatives effective for management of sugarbeet root maggot, cutworms, leafminers, or armyworms.

23.7 Grower Perspectives

In late 2007, the EPA asked for public comments on issues related to the agricultural use of chlorpyrifos. The following is a selection of excerpts from growers who responded to the EPA's request for input by explaining why they considered chlorpyrifos essential for protecting their crops. Submissions to the docket are public information and have been posted by the EPA at www.regulations.gov, docket number EPA-HQ-OPP-2007-1005. Growers also commented during public comment periods in 2011 (EPA-HQ-OPP-2008-0850-0025) and 2015 (EPA-HQ-OPP-0850-0224).

"Chlorpyrifos is an important tool in pest management for sugarbeet production in [Southern Idaho]. It provides a much-needed change in chemical formulation to help prevent sugarbeet root maggot resistance... It helps ensure that good quality products are produced to meet market demands and consumer preference. When used properly, chlorpyrifos only improves the quality that we work so hard to provide." – Jentzsch-Kearl Farms

"Our sugarbeet acres occasionally require treatment for the control of cutworm and sugarbeet root maggot. Both of these pests have a major impact on yield. The American sugarbeet growers have very few options when these pests reach beyond economic thresholds... We will be among the first to adapt to better control methods when they become available... Until then, please maintain one of the few tools we have to control the serious pest problems that confront us." – North Dakota grower

23.8 **References**

1. Pacific Northwest Insect Management Handbook. *Sugar Beet-Sugar Beet Root Maggot* 2015. http://insect.pnwhandbooks.org/agronomic/sugar-beet/sugar-beet-sugar-beet-root-maggot. Accessed December 16, 2015.
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3. University of California, UC IPM Online. *How to Manage Pests, Sugarbeet/Armyworms.* January 2010. http://www.ipm.ucdavis.edu/PMG/r735300811.html. Accessed December 16, 2015.
4. University of California, U.C. IPM Online. *Sugarbeet-Leafminers.* November 2005. http://www.ipm.ucdavis.edu/PMG/r735301611.html. Accessed December 16, 2015.

24. Sunflowers

24.1 Overview

Over 1.6 million acres of sunflowers were grown annually in the U.S. in 2012-2014, a 27% decrease from the 2003-2007 average of 2.2million acres. Nearly 80% of the sunflowers were grown in two states, North Dakota and South Dakota, while the rest were grown in Colorado, Kansas, Minnesota, Nebraska and Texas.

Table 148. U.S. Sunflower Production – Acres Planted 2012-2014.

State	Acres Planted			
	2012	2013	2014	2012-2014 Average
NORTH DAKOTA	860,020	499,007	695,000	684,675
SOUTH DAKOTA	644,977	680,009	625,000	649,995
TEXAS	94,000	113,002	120,001	109,001
COLORADO	85,999	67,000	64,999	72,666
KANSAS	86,998	70,999	58,000	71,999
MINNESOTA	49,000	42,999	49,000	47,000
NEBRASKA	42,000	42,999	35,000	40,000
U.S. Total	**1,862,993**	**1,516,015**	**1,647,000**	**1,675,336**

Source: Third party proprietary data.

24.2 Chlorpyrifos Use

Chlorpyrifos was the third most-used active ingredient in controlling insect pests in sunflowers, and was used on an average of 11.7% of the active ingredient treated acres in 2012-2014. Chlorpyrifos was among the most-used active ingredients for controlling primary sunflower insect pests including weevils, sunflower moth, grasshoppers, cutworm, and sunflower beetle. Maintaining the availability of chlorpyrifos in the sunflower insecticide complex is important for the control of these insect pests, and the viability of long-term resistance management programs.

Table 149. Leading Insecticide Active Ingredients Used in Sunflower – Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CYHALOTHRIN-LAMBDA	715,026	813,822	657,775	728,875	43.5%
ESFENVALERATE	465,687	286,880	293,005	348,524	20.8%
CHLORPYRIFOS	167,872	164,314	255,033	195,740	11.7%
CYFLUTHRIN	129,572	69,783	104,477	101,277	6.0%
CYHALOTHRIN-GAMMA	123,276	44,553	120,758	96,196	5.7%
DELTAMETHRIN	98,017	85,149	99,449	94,205	5.6%
U.S. Total	**1,774,383**	**1,553,464**	**1,696,355**	**1,674,734**	**Column Total 93.4%**

Source: Proprietary third party data. Excluding seed treatments.

Growers used an average of 68,479 lb a.i. of chlorpyrifos annually to control insect pests in sunflowers in 2012-2014, nearly twice the average annual use in 2003-2007 (34,857 lb a.i.). The increase in chlorpyrifos use occurred despite a significant decline in sunflower acreage from the 2003-2007 period.

Table 150. Chlorpyrifos Use in Sunflowers – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	167,872	164,314	255,033	195,740
Lb a.i. Applied	66,678	47,551	91,209	68,479

Source: Proprietary third party data.

24.3 Target Pests

The primary insect pests in sunflowers include weevils (seed, red sunflower seed, stem), sunflower moth, grasshoppers, cutworm and sunflower beetle.

Table 151. Top Insect Pests in Sunflowers – Pest Acres 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
WEEVIL, SEED	416,203	561,221	594,407	523,944	31.3%
MOTH, SUNFLOWER	421,564	255,676	305,196	327,479	19.6%
WEEVIL, RED SUNFLOWER SEED	322,482	133,652	111,623	189,252	11.3%
GRASSHOPPER	263,189	170,350	112,165	181,901	10.9%
CUTWORM	154,876	132,321	110,455	132,550	7.9%
WEEVIL, STEM	102,506	97,860	103,322	101,229	6.0%
BEETLE, SUNFLOWER	101,852	81,785	115,507	99,715	6.0%
U.S. Total	**2,295,101**	**1,911,508**	**2,095,966**	**2,100,858**	**Column Total 92.9%**

Source: Proprietary third party data. Excluding seed treatments.

Chlorpyrifos is among the leading insecticides used to control all of the primary insect pests in sunflowers. Pyrethroids accounted for 85.3% of total active ingredient acres used to control insect pests in sunflower in 2012-2014. Chlorpyrifos was the most-used non-pyrethroid insecticide. Effective non-pyrethroid insecticides, like chlorpyrifos, are needed to help manage resistance development.

Table 152. Leading Insecticide Active Ingredients Used to Control Weevils (Seed, Red Sunflower Seed, Stem) in Sunflowers – Pest Acres 2012-2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CYHALOTHRIN-LAMBDA	303,253	375,055	309,475	329,261	41.9%
ESFENVALERATE	315,366	189,387	244,728	249,827	31.8%
CHLORPYRIFOS	53,994	98,746	120,773	91,171	11.6%
DELTAMETHRIN	57,019	30,072	36,544	41,212	5.2%
CYFLUTHRIN	24,230	26,502	30,702	27,144	3.5%
CYHALOTHRIN-GAMMA	4,696	21,966	39,687	22,116	2.8%
U.S. Total	**792,689**	**752,668**	**810,690**	**785,349**	**Column Total 96.9%**

Source: Proprietary third party data. Excluding seed treatments.

Table 153. Leading Insecticide Active Ingredients Used to Control Sunflower Moth in Sunflowers – Pest Acres 2012-2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CYHALOTHRIN-LAMBDA	153,386	140,180	115,554	136,373	41.6%
CHLORPYRIFOS	83,783	44,459	57,888	62,043	18.9%
CYHALOTHRIN-GAMMA	86,095	7,017	15,184	36,099	11.0%
ESFENVALERATE	32,381	22,016	25,665	26,687	8.1%
CYFLUTHRIN	34,130	13,864	22,789	23,594	7.2%
ZETA-CYPERMETHRIN	10,945	9,147	22,549	14,214	4.3%
U.S. Total	**421,564**	**255,676**	**305,196**	**327,479**	**Column Total 91.3%**

Source: Proprietary third party data. Excluding seed treatments.

Table 154. Leading Insecticide Active Ingredients Used to Control Sunflower Beetle in Sunflowers – Pest Acres 2012-2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
ESFENVALERATE	40,382	53,880	15,322	36,528	36.6%
CYHALOTHRIN-LAMBDA	32,515	5,792	18,400	18,902	19.0%
CHLORPYRIFOS	--	--	43,281	14,427	14.5%
CYHALOTHRIN-GAMMA	--	2,130	35,130	12,420	12.5%
DELTAMETHRIN	4,568	13,284	3,374	7,075	7.1%
CYFLUTHRIN	7,321	--	--	2,440	2.4%
U.S. Total	**101,852**	**81,785**	**115,507**	**99,715**	**Column Total 92.1%**

Source: Proprietary third party data. Excluding seed treatments.

24.4 Benefits of Chlorpyrifos in Sunflowers

- Effective control of the primary insect pests in sunflowers including weevils (seed, red sunflower seed, stem), sunflower moth, grasshoppers, cutworm, and sunflower beetle as well as other economically important insect pests.
- Provides broad spectrum control - The availability of chlorpyrifos also allows sunflower growers to control a broad spectrum of insects in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests. Some alternative insecticides do not provide broad spectrum control and, as a result, multiple insecticide applications may be required to

control multiple insect pests. For example, chlorantraniliprole controls sunflower moth, but not weevils or sunflower beetles, and would require an additional insecticide treatment to control these insect pests.

- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance. Pyrethroids (Group 3) are used extensively because they are inexpensive and broad spectrum. The availability of chlorpyrifos allows growers to rotate between different insecticide modes of action, which helps delay resistance development in all insecticides. Resistance development to pyrethroids would proceed at an accelerated rate in the absence of chlorpyrifos.
- Cost effective.

24.5 Chlorpyrifos Formulations, Rates, and Applications

Current chlorpyrifos formulations listed for controlling insect pests in sunflowers include Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, Lorsban 15G (and other chlorpyrifos granular formulations), Cobalt, and Cobalt Advanced.

Location: Midwest – ND, SD, CO, NE, KS

- Product: Lorsban 15G
- Pest: cutworms
- Application Type: ground
- Application Method: preplant incorporated
- Rate: 0.5-1.0 lb a.i./A
- Number of Applications: 1
- Timing of Applications: prior to plant

Location: Midwest – ND, SD, CO, NE, KS

- Product: Lorsban-4E, Lorsban Advanced, Cobalt
- Pest: banded sunflower moth, seed weevil, stem weevil, sunflower beetle larvae and adults, sunflower moth, woolly bears
- Application Type: ground, air, chemigation
- Application Method: broadcast
- Rate: 0.25-0.75 lb a.i./A
- Number of Applications: 1
- Timing of Applications: post

Location: Midwest – ND, SD, CO, NE, KS

- Product: Lorsban-4E, Lorsban Advanced, Cobalt
- Pest: cutworms
- Application Type: ground, air, chemigation
- Application Method: broadcast
- Rate: 1.0 lb a.i./A

- Number of Applications: 1
- Timing of Applications: post

Table 155. Leading Chemical Treatments for Insect Control in Sunflowers.

Note: Information in the "Benefits, Application, Use and Efficacy" section reflect opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Benefits, Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, Lorsban 15G Others	-Controls banded sunflower moth, cutworm, grasshopper, sunflower beetle, sunflower moth, sunflower seed weevil and stem weevil. -Broad spectrum. -Group 1B MOA for resistance management. -Cost effective.
Chlorpyrifos + Gamma-Cyhalothrin/ Chlorpyrifos + Lambda-Cyhalothrin	Cobalt/ Cobalt Advanced	-Controls banded sunflower moth, cutworm, grasshopper, sunflower beetle, sunflower moth, sunflower seed weevil and stem weevil. -Broad spectrum. -Groups 1B and 3A MOA for resistance management. -Cost effective.
Chlorantraniliprole	Prevathon	-Controls Banded sunflower moth, sunflower moth. -Group 28 MOA. -Relatively expensive.
Esfenvalerate	Asana	-Controls banded sunflower moth, cutworm, grasshopper, sunflower beetle, sunflower moth, sunflower seed weevil and stem weevil. -Broad spectrum. -Group 3A MOA. -Cost effective.
Cyfluthrin	Baythroid, others	-Controls banded sunflower moth, cutworm, grasshopper, sunflower beetle, sunflower moth, sunflower seed weevil and stem weevil. -Broad spectrum. -Group 3A MOA. -Cost effective.
Gamma-Cyhalothrin	Proaxis, others	--Controls banded sunflower moth, cutworm, grasshopper, sunflower beetle, sunflower moth, sunflower seed weevil and stem weevil. -Broad spectrum. -Group 3A MOA. -Cost effective.
Lambda-Cyhalothrin	Warrior, others	-Controls banded sunflower moth, cutworm, grasshopper, sunflower beetle, sunflower moth, sunflower seed weevil and stem weevil. -Broad spectrum. -Group 3A MOA.

Active Ingredient	Brand Names	Benefits, Application, Use, and Efficacy
		-Cost effective.
Zeta-Cypermethrin	Mustang, others	-Controls banded sunflower moth, cutworm, grasshopper, sunflower beetle, sunflower moth, sunflower seed weevil and stem weevil. -Broad spectrum. -Group 3A MOA. -Cost effective.

25. Sweet Corn

25.1 Overview

Over 527,000 acres of sweet corn was grown annually in the U.S. in 2012-2014. While sweet corn is grown in all 50 states, the production of sweet corn for processing is heavily concentrated in the upper Midwest and the Pacific Northwest. Coastal states dominate the commercial fresh sweet corn market, and Florida is the leading producer of fresh sweet corn [1].

Table 156. U.S. Sweet Corn Production – Acres Planted 2012-2014.

State	Acres Planted			
	2012	2013	2014	2012-2014 Average
MINNESOTA	132,200	132,200	116,600	127,000
WASHINGTON	97,800	97,800	81,200	92,267
WISCONSIN	82,800	82,800	73,800	79,800
FLORIDA	49,000	49,000	40,500	46,167
NEW YORK	38,105	38,105	26,207	34,139
CALIFORNIA	34,000	34,000	32,200	33,400
GEORGIA	28,000	28,000	23,700	26,567
OREGON	23,340	23,340	22,558	23,079
OHIO	16,400	16,400	15,900	16,233
ILLINOIS	16,930	16,930	14,610	16,157
PENNSYLVANIA	16,963	16,963	12,412	15,446
MICHIGAN	10,100	10,100	9,700	9,967
NEW JERSEY	7,956	7,956	6,992	7,635
U.S. Total	**553,594**	**553,594**	**476,379**	**527,856**

Source: Third party proprietary data.

Table 157. U.S. Sweet Corn Production for Fresh Market and Processing – Acres Planted 2012-2014.

Type	Area Planted (000 acres)			
	2012	2013	2014	2012-2014 Average
Fresh market	234	244	230	236
Processing	367	329	325	340
Total U.S.	**601**	**573**	**555**	**576**

Source: USDA, NASS.

25.2 Chlorpyrifos Use

Chlorpyrifos was the eighth most-used active ingredient in controlling insect pests in sweet corn, and was used on an average of 2.3% of total active ingredient treated acres.

Table 158. Leading Insecticide Active Ingredients Used in Sweet Corn – Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CYHALOTHRIN-LAMBDA	564,782	1,006,332	771,870	780,995	26.4%
METHOMYL	576,596	511,104	679,459	589,053	19.9%
BIFENTHRIN	467,857	791,111	468,853	575,940	19.5%
ZETA-CYPERMETHRIN	322,076	219,884	195,959	245,973	8.3%
ESFENVALERATE	155,722	118,678	195,044	156,481	5.3%
SPINETORAM	135,786	123,949	42,874	100,870	3.4%
CYFLUTHRIN	117,296	52,730	48,115	72,714	2.5%
CHLORPYRIFOS	70,297	43,941	91,637	68,625	2.3%
U.S. Total	**2,705,504**	**3,311,311**	**2,844,443**	**2,953,753**	**Column Total 87.7%**

Source: Proprietary third party data. Excluding seed treatments.

Growers used an average of 66,994 lb a.i. of chlorpyrifos annually to control insect pests in sweet corn in 2012-2014, a 45% decrease from the average annual use in 2003-2007 (120,881 lb a.i.).

Table 159. Chlorpyrifos Use in Sweet Corn – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	70,297	43,941	91,637	68,625
Lb a.i. Applied	75,195	50,010	75,775	66,994

Source: Proprietary third party data.

25.3 Target Pests

Corn ear worm, European corn borer, armyworm, corn rootworm, silk fly, cutworm and aphids were the top target pests in sweet corn, and accounted for 145% of the total active ingredient acres. According to the University of Florida IFAS Extension, "foliar, ear and root feeding insects can routinely cause economic losses to sweet corn if left untreated. The most important pests of sweet corn in Florida are the fall armyworm, corn earworm, lesser cornstalk borer, cutworms, corn silk fly, cucumber beetles, aphids, and wireworms" [2].

Table 160. Top Insect Pests in Sweet Corn – Pest Acres 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
WORM, CORN EAR	1,438,612	2,485,042	1,196,438	1,706,698	57.8%
BORER, EUROPEAN CORN	767,702	825,033	706,195	766,310	25.9%
ARMYWORM, FALL	192,654	765,923	805,740	588,106	19.9%
ROOTWORM, CORN	128,042	435,540	326,020	296,534	10.0%
ARMYWORM	432,234	174,985	141,161	249,460	8.4%
FLY, SILK	233,316	95,741	389,488	239,515	8.1%
CUTWORM	119,231	506,474	68,523	231,410	7.8%
APHID	57,173	501,129	53,475	203,926	6.9%
U.S. Total	**4,124,953**	**6,527,182**	**4,432,246**	**5,028,127**	**Column Total 145.0%**

Source: Proprietary third party data. Excluding seed treatments.

Because of its broad spectrum control, chlorpyrifos was used in Florida and Georgia to control silk fly, cutworm, corn earworm, and fall armyworm. In the Midwest, corn rootworm was the insect pest most often targeted with chlorpyrifos, followed by cutworm, European corn borer, armyworm, and grubs. In Western region states, chlorpyrifos was used most to control symphylan, followed by cutworm, corn rootworm and corn earworm. In the Atlantic region, chlorpyrifos use was primarily for corn rootworm control.

25.4 Benefits of Chlorpyrifos in Sweet Corn

- Effective control of the primary insect pests in sweet corn, including corn ear worm, European corn borer, armyworm, corn rootworm, silk fly, cutworm, and aphids as well as other economically important insect pests.
- Provides broad spectrum insect control – The availability of chlorpyrifos also allows sweet corn growers to control a broad spectrum of insects in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests. Some alternative insecticides do not provide broad spectrum control and, as a result, multiple insecticide applications may be required to control multiple insect pests. For example, chlorantraniliprole and flubendiamide control corn earworm, cutworm, and armyworm, but not symphylan, silk fly, or corn rootworm, and would require an additional insecticide treatment to control these insect pests.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance. Control of many of the insect pests in sweet corn, such as the corn earworm, requires multiple sequential applications. Therefore, there is a great need for alternative efficacious products that can be rotated to delay resistance. Chlorpyrifos is a valuable component in an insect

resistance management program due to its broad spectrum and Group 1B mode of action. Pyrethroid (Group 3A) and carbamate (Group 1A) insecticides are used to control target pests in sweet corn, and have known insect resistance.
- Cost effective.

25.5 Chlorpyrifos Formulations, Rates, and Applications

Current chlorpyrifos formulations listed for controlling insect pests in sweet corn include Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, Lorsban 15G (and other chlorpyrifos granular formulations), Cobalt, and Cobalt Advanced.

Location: Pacific Northwest
- Pests: corn earworm
- Application Type: ground, chemigation, aerial
- Application Method: broadcast
- Rate: 0.25-1.0 lb a.i./A
- Number of Applications: 1-3
- Timing of Application: during the Summer

Location: FL
- Pests: fall armyworm, corn earworm, silk fly
- Application Type: ground and aerial
- Application Method: low pressure sprayers
- Rate: 0.5-1.0 lb a.i./A
- Number of Applications: 3 (max)
- Timing of Application: October-June

Location: Midwest and Northeast
- Pest: armyworm, cutworms
- Application Type: ground, air, chemigation
- Application Method: broadcast
- Rate: 0.5-1.0 lb a.i./A
- Number of Applications: 1
- Timing of Application: preplant, at-plant, preemergence

Location: Midwest and Northwest
- Pest: armyworm, cutworms, aphids, rootworm adults, European corn borer, flea beetle
- adults, southern corn leaf beetle, webworms, western bean cutworm
- Application Type: ground, air, chemigation
- Application Method: broadcast
- Rate: 0.5-1.0 lb a.i./A

- Number of Applications: 1
- Timing of Application: post to corn emergence

Location: Midwest and Northeast

- Pest: corn earworm
- Application Type: ground, air, chemigation
- Application Method: broadcast
- Rate: 0.75-1.0 lb a.i./A
- Number of Applications: 1
- Timing of Application: post to corn emergence

Location: Midwest and Northwest

- Pest: rootworms, cutworms, wireworm, lesser seed corn borer, billbugs
- Application Type: ground
- Application Method: at plant
- Rate: 1.30 lb a.i./A (granular)
- Number of Applications: 1
- Timing of Application: at planting

Location: Midwest

- Pest: European corn borer
- Application Type: aerial, ground
- Application Method: broadcast or directed
- Rate: 0.75-1.0 lb a.i./A (granular)
- Number of Applications: 1
- Timing of Application: in relation to corn growth from V9 to R1

25.6 Grower Perspective

In late 2007, the EPA asked for public comments on issues related to the agricultural use of chlorpyrifos. Following is an excerpt explaining why chlorpyrifos is essential for protecting crops. Submissions to the docket are public information, and have been posted by the EPA at www.regulations.gov, docket number EPA-HQ-OPP-2007-1005. Growers also commented during public comment periods in 2011 (EPA-HQ-OPP-2008-0850-0025) and 2015 (EPA-HQ-OPP-0850-0224).

"Chlorpyrifos is widely used in Oregon as a seed treatment to control pests that feed on snap bean and sweet corn and young seedlings...Producers also use it on sweet corn at planting, to help control corn rootworm larvae, cutworms and symphylans. Growers have not found alternative products that offer the control of chlorpyrifos. Elimination of chlorpyrifos would have significant negative impacts on Oregon growers' ability to competitively produce processed vegetable crops and consequently would severely hamper the entire processed vegetable industry in the state." – Oregon Processed Vegetable Commission.

Other Perspectives
In preparing this report, growers and crop consultants were asked to share their thoughts on the benefits and use of chlorpyrifos for pest control.

"We need Lorsban in our pest management rotation, as it is one of only a few organophosphates left that control silk flies in sweet corn. Right now, silk flies are a major pest and require frequent sprays. Growers use chlorpyrifos at tassel push and green silk. Lorsban is also used on lesser corn stalk borer and wireworms." – Loren Horseman, Glades Crop Care (April 2009).

25.7 References

1. Agricultural Marketing Resource Center. *Sweet Corn*. November 2013. http://www.agmrc.org/commodities-products/grains-oilseeds/corn-grain/sweet-corn/. Accessed December 15, 2015.

26. Sweet Potatoes

26.1 Overview

An average of 127,800 acres of sweet potatoes was planted annually in the U.S. in 2012-2014. Over 75% of sweet potatoes were produced in the Southern states, and nearly 15% were grown in California.

Table 161. U.S. Sweet Potato Production – Acres Grown 2012-2014.

State	Acres Planted (000)			
	2012	2013	2014	2012-2014 Average
NORTH CAROLINA	63	54	73	63
MISSISSIPPI	24	20	22	22
CALIFORNIA	18	19	19	19
LOUISIANA	10	8	9	9
OTHER STATES	15.5	14.7	14.3	15
U.S. Total	**130.5**	**115.7**	**137.3**	**127.8**

Source: USDA, NASS.

26.2 Chlorpyrifos Use

No information was available on the number of treated acres or lb a.i. of chlorpyrifos applied on sweet potatoes. University insect management guides recommend chlorpyrifos to control several economically important insect pests including wireworm, sweet potato flea beetle and other flea beetle species in sweet potatoes.

26.3 Target Pests

Several insect pests including rootworms, wireworms, white grubs, sweetpotato flea beetle, sweetpotato weevil and tortouise beetle can cause damage to sweet potatoes. The use of chlorpyrifos as a preplant treatment has been a foundation insecticide for sweet potato growers for control of sweetpotato flea beetle and wireworm [1] [2] [3]. Market tolerance for cosmetic injury in this crop is very low, and insect damage can drastically affect marketability.

26.3.1 Sweetpotato Flea Beetle

Adults feed on foliage leaving channels on the upper leaf surfaces. Larvae feed on roots etching shallow, winding, sunken, trails on the surface, which enlarge, darken and split. There are several generations per year. Preplant or side-dressed insecticides are used to control sweetpotato flea beetle up to the last cultivation. Foliar insecticides are used to control adults [1].

Soil applied chlorpyrifos, bifenthrin, clothianidin, ethoprop, imidacloprid and thiamethoxam are recommended for sweetpotato flea beetle control. Chlorpyrifos provides sweetpotato flea beetle control equal to bifenthrin and thiamethoxam, and superior to ethoprop. Imidacloprid provides the highest level of control, and ratings for clothianidin were not available [3].

26.3.2 Wireworms

Tobacco wireworm, southern potato wireworm, and corn wireworm leave small, irregular, holes in the surface of sweetpotato roots. Soil applied insecticides are recommended for wireworm control. Foliar sprays that target adults to prevent egg laying do not provide any reduction in larvae root damage at harvest [1]. Soil applied chlorpyrifos, bifenthrin, clothianidin and ethoprop are recommended for wireworm control. Chlorpyrifos provides superior wireworm control compared to bifenthrin and ethoprop. Clothianidin control ratings were not available [3]. Research has shown that the best control is achieved when chlorpyrifos is applied as a broadcast preplant application incorporated 4-6 inches deep prior to bed formation, followed by one or more soil-directed, incorporations of bifenthrin during routine cultivation.

26.4 Benefits of Chlorpyrifos in Sweet Potato

- Superior control of wireworm and effective control of sweetpotato flea beetle.
- Active on soil-dwelling insect pests.
- Good rotational partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.

26.5 Chlorpyrifos Formulations, Rates, and Applications

Current chlorpyrifos formulations listed for controlling insect pests in sweet potatoes include Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, and Lorsban 15G (and other chlorpyrifos granular formulations).

Location: CA, LA, NC (do not use in MS)

- Product: Lorsban 4-E or Lorsban 15G
- Pests: wireworms, flea beetles
- Application Type: ground
- Application Method: broadcast preplant incorporated
- Rate: 2.0 lb a.i./A
- Number of applications: 1
- Timing of Application: preplant

26.6 Non-Chemical Alternatives

Resistant or tolerance varieties are used to reduce sweetpotato flea beetle and wireworm losses. Avoid land previously in sod, fallow, corn, grain or grain sorghum to reduce the likelihood of damaging wireworm populations, and control weeds.

26.7 **References**

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http://ipm.ncsu.edu/vegetables/Pamphlets/sweetpotato/sweetpotato.html. Accessed December 25, 2015.

27. Tobacco

27.1 Overview

An average of 358,168 acres of tobacco were grown annually in the U.S. in 2012-2014. North Carolina, Kentucky, Virginia and Tennessee accounted for 90% of the tobacco grown in the U.S.

Table 162. U.S. Tobacco Production – Acres Planted 2012-2014.

State	Acres Planted			
	2012	2013	2014	2012-2014 Average
NORTH CAROLINA	166,101	172,300	192,251	176,884
KENTUCKY	87,200	92,500	100,662	93,454
VIRGINIA	23,080	25,100	32,896	27,025
TENNESSEE	23,800	21,500	27,396	24,232
GEORGIA	10,500	15,000	14,843	13,448
SOUTH CAROLINA	13,501	9,000	12,527	11,676
PENNSYLVANIA	9,600	8,900	9,671	9,390
OHIO	1,800	2,500	1,876	2,059
U.S. Total	**335,582**	**346,800**	**392,122**	**358,168**

Source: Proprietary third party data.

27.2 Chlorpyrifos Use

Although chlorpyrifos use in tobacco averaged only 3.7% of all active ingredient acres treated on this crop in 2012-2014, it is an important tool in U.S. tobacco production systems. Growers used an average of 44,720 lb a.i. of chlorpyrifos annually to control insect pests in tobacco in 2012-2014, a 55% decrease in average annual use from 2003-2007 (98,468 lb a.i.). Chlorpyrifos was the most-used insecticide for control of wireworms, and second most-used insecticide for control of cutworm in tobacco. Maintaining the availability of chlorpyrifos in the tobacco insecticide complex is important for control of these insect pests, and the viability of long-term resistance management programs.

Table 163. Chlorpyrifos Use in Tobacco – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	40,697	19,830	60,810	40,446
Lbs a.i. Applied	49,264	16,282	68,614	44,720

Source: Proprietary third party data.

27.3 Target Pests

While bud worm, tobacco horn worm, flea beetle, tobacco aphid and cutworm were the top target pests in tobacco; other insect pests like wireworm can damage thousands of acres of tobacco. Chlorpyrifos provides broad spectrum control of a number of insect pests in tobacco including cutworms, flea beetles, mole crickets, root maggots and wireworm.

Table 164. Top Insect Pests in Tobacco – Acres Treated 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
WORM, BUD	459,564	403,120	512,405	458,363	27.4%
HORNWORM, TOBACCO	420,914	258,923	239,966	306,601	18.3%
WORM, HORN	164,958	245,994	186,679	199,210	11.9%
BEETLE, FLEA	170,351	113,341	118,573	134,088	8.0%
APHID, TOBACCO	86,358	72,005	135,264	97,876	5.9%
CUTWORM	84,346	83,009	93,699	87,018	5.2%
U.S. Total	**1,717,357**	**1,610,171**	**1,689,559**	**1,672,362**	**Column Total 76.7%**

Source: Proprietary third party data. Excluding seed treatments.

27.3.1 Wireworm

Wireworms damage tobacco by tunneling into the stalk below the soil surface. This may kill or stunt plants, and possibly open even resistant varieties to soil-borne diseases. Stunting and the need to reset plants can result in an uneven, costly, and difficult-to-manage crop. Under good growing conditions, tobacco usually recovers from wireworm damage with little to no yield loss. However, if conditions are less favorable or if certain diseases are present, yield may be reduced [1].

Chlorpyrifos was the primary insecticide active ingredient used to control wireworm in tobacco, and was used on 51% of the pest acres treated for wireworm in 2012-2014.

Table 165. Leading Insecticide Active Ingredients Used to Control Wireworm in Tobacco – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CHLORPYRIFOS	16,858	7,490	27,588	17,312	51.0%
ACEPHATE	6,880	776	11,845	6,501	19.1%
IMIDACLOPRID	1,593	2,427	5,950	3,323	9.8%
BIFENTHRIN	1,373	4,330	837	2,180	6.4%
THIAMETHOXAM	3,422	1,150	--	1,524	4.5%
U.S. Total	**30,125**	**24,658**	**47,061**	**33,948**	Column Total **90.8%**

Source: Proprietary third party data. Excluding seed treatments.

27.3.2 Cutworm

A number of cutworm species feed on tobacco including the variegated, black, and spotted cutworm. Cutworm feeding begins as small, webless holes on young leaves. As the larvae grow, they begin their typical cutting behavior [2].

Chlorpyrifos was the second most-used insecticide active ingredient to control cutworm in tobacco, and was used on 21.3% of the pest acres treated for wireworm in 2012-2014.

Table 166. Leading Insecticide Active Ingredients Used to Control Cutworm in Tobacco – Pest Acres 2012–2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
ACEPHATE	38,725	33,991	43,801	38,839	44.6%
CHLORPYRIFOS	18,870	9,454	27,308	18,544	21.3%
BIFENTHRIN	5,756	10,479	7,036	7,757	8.9%
IMIDACLOPRID	6,914	9,896	1,626	6,145	7.1%
CYHALOTHRIN-LAMBDA	4,977	6,542	3,684	5,068	5.8%
U.S. Total	**84,346**	**83,009**	**93,699**	**87,018**	Column Total **87.7%**

Source: Proprietary third party data. Excluding seed treatment.

27.4 Benefits of Chlorpyrifos in Tobacco

- Chlorpyrifos is the insecticide most used for wireworm control, and second most-used insecticide for cutworm control.
- Effective control of several primary insect pests in tobacco, including cutworm and flea beetle, as well as other economically important insect pests such as wireworm.
- Provides broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance
- Lower mammalian toxicity compared to ethoprop.

27.5 Chlorpyrifos Formulations, Rates, and Applications

The formulations listed for controlling insect pests in tobacco include Lorsban-4E (and other 4 lbs per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, and Lorsban 15G (and other chlorpyrifos granular formulations).

Location: Southern states (NC, KY, VA, TN)

- Pests: wireworms, cutworm, flea beetles
- Application Type: soil
- Application Method: broadcast and incorporate prior to transplanting
- Rate: 1.0 lb a.i./A
- Number of Applications: 1
- Season of Application: prior to transplanting

Table 167. Leading Chemical Treatments for Insect Control in Tobacco.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, Lorsban 15G, others	-Pre-transplant soil treatment for control of wireworm, cutworm, root maggot, mole cricket and flea beetle. -Broad spectrum. -Group 1B MOA for resistance management. -Cost effective.
Acephate	Several	-Rescue treatment for cutworm. -Group 1B MOA.
Bifenthrin	Capture, others	-Pre-transplant soil treatment for control of wireworm. -Limited data on wireworm control. -Group 3A MOA.
Bifenthrin + Imidacloprid	Brigadier	-Transplant water treatment for suppression of wireworm and control of early season aphids and flea beetle. -Groups 3A and 4A MOA.
Chlorantraniliprole	Coragen	-Rescue treatment for cutworm.

Active Ingredient	Brand Names	Application, Use, and Efficacy
		-Group 28 MOA.
Chlorantraniliprole + Lambda-Cyhalothrin	Besiege	-Rescue treatment for cutworm. -Long PHI – 40 days. -Groups 28 and 3A MOA.
Ethoprop	Mocap	-Pre-transplant soil treatment for control of wireworm and corn rootworm. -Highly toxic. -Group 1B MOA.
Flubendiamide	Belt	-Rescue treatment for cutworm. -Group 28 MOA.
Imidacloprid	Several	-Greenhouse tray drench or transplant water treatment for suppression of wireworm and control of early season aphid and flea beetle. -Group 4A MOA.
Lambda-Cyhalothrin	Warrior, Karate, others	-Rescue treatment for cutworm. -Long PHI – 40 days. -Group 3A MOA.
Thiamethoxam	Platinum	-Greenhouse tray drench or transplant water treatment for suppression of wireworm and control of early season aphid and flea beetle. -Group 3A MOA.

Source: [3].

27.6 Non-Chemical Alternatives

Soil dwelling entomopathenogenic nematodes and fungi may infect wireworm larvae. Limited trials with commercial versions of these biological control agents in other crops have shown variable results [1].

The likelihood of cutworm problems can be reduced by controlling weeds the previous year, and preparing the soil 4 to 6 weeks before tobacco plants are transplanted [2].

27.7 References

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28. Tree Nuts (almonds, pecans, walnuts)

28.1 Overview

Tree nut crops including almonds, walnuts, pecans, and filberts were grown on nearly 1.8 million acres in 2012-2014, a 7.9% from the average acres grown in 2004-2007 (1,665,183 acres). Tree nut production since the mid-2000s has generated nearly $4 billion in annual U.S. farm cash receipts, with almonds, walnuts, and pecans accounting for most of the sales. California is the leading producer of tree nuts. Nearly 90% of U.S. tree nut production is harvested from California orchards annually, including virtually all almonds and walnuts. Georgia, New Mexico, Oklahoma, and Texas produce only pecans. Other smaller nut crops include filberts in Oregon and macadamia nuts in Hawaii [1]. Filberts (hazelnuts) are not included in this section, and are addressed in a separate "Filbert" section in this document.

Table 168. U.S. Tree Nut Production (Excluding Pistachios and Macadamia Nuts) – Acres Grown 2012-2014.

Nut Crop	Acres Grown			
	2012	2013	2014	2012-2014 Average
Almonds	963,009	963,009	983,948	969,989
Hazelnuts	34,132	34,132	37,159	35,141
Pecans	500,466	500,466	467,336	489,423
Walnuts	297,278	297,278	352,421	315,659
Total U.S.	**1,794,885**	**1,794,885**	**1,840,864**	**1,794,885**

Source: Proprietary third party data.

Texas, Georgia and Oklahoma together grow more than 85% of total pecan acres.

Table 169. U.S. Pecan Production – Acres Grown 2014.

State	Acres Grown	% of Total Acres Grown
TEXAS	164,882	35.1%
OKLAHOMA	104,307	26.4%
GEORGIA	123,415	24.0%
NEW MEXICO	41,331	8.2%
ALABAMA	16,340	3.6%
ARIZONA	17,061	2.8%
Total U.S.	**467,336**	**100%**

Source: Proprietary third party data.

28.2 Chlorpyrifos Use in Tree Nuts

Growers used an average of 928,920 lb a.i. of chlorpyrifos annually to control insect pests in tree nut crops in 2012-2014, a 24% decrease from the average annual use in 2003-2007 (1,218,872 lb a.i.). Almonds and walnuts accounted for over 80% of the chlorpyrifos used, and pecans for nearly 18% in 2012-2014.

Table 170. Chlorpyrifos Use in Tree Nuts – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	Lbs a.i. Applied				% of Total Lbs a.i. Applied (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
Almonds	256,220	566,656	289,663	370,846	39.9%
Pecans	205,087	127,474	165,395	165,985	17.9%
Walnuts	344,137	344,272	487,857	392,089	42.2%
U.S. Total	**805,444**	**1,038,402**	**942,915**	**928,920**	**100.0%**

Source: Proprietary third party data.

28.3 Almonds

Although chlorpyrifos use in almonds in 2012-2014 averaged only 4.4% of all active ingredient acres treated on this crop, it is an important tool in U.S. almond crop production systems. Chlorpyrifos was used to control navel orangeworm and peach twig borer, the two most important insect pests in almonds, as well as other economically important insect pests. Maintaining the availability of chlorpyrifos in the almond crop insecticide complex is important for control of this insect pest, and the viability of long-term resistance management programs.

Table 171. Leading Insecticide Active Ingredients Used in Almonds – Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
ABAMECTIN	899,912	962,707	934,485	932,368	20.6%
PETROLEUM OIL	412,917	638,243	521,139	524,100	11.6%
METHOXYFENOZIDE	254,900	573,124	712,332	513,452	11.4%
BIFENTHRIN	361,068	411,998	274,895	349,321	7.7%
CHLORANTRANILIPROLE	222,697	334,833	367,617	308,382	6.8%
ESFENVALERATE	316,796	259,399	230,607	268,934	6.0%
ETOXAZOLE	88,595	249,395	294,696	210,895	4.7%
CHLORPYRIFOS	137,660	302,825	161,101	200,529	4.4%
CYHALOTHRIN-LAMBDA	158,578	177,600	239,386	191,855	4.2%
U.S. Total	**3,689,768**	**4,964,832**	**4,892,732**	**4,515,777**	**77.5%**

Source: Proprietary third party data.

Some variation in acres treated and lbs a.i. applied were found comparing CDPR and proprietary third party data for chlorpyrifos use in almonds.

Table 172. Chlorpyrifos Use in California Almonds –Lb Acres Treated and A.I. Applied 2012-2014.

Almonds	Data Source	2012	2013	2014	2012-2014 Average
Acres Treated	CDPR	106,370	239,558	160,276	168,735
	Third party proprietary	137,660	302,825	161,101	200,529
Lb a.i. Applied	CDPR	190,884	446,206	296,296	311,129
	Third party proprietary	256,220	566,656	289,663	370,846

28.3.1 Target Pests

The two primary pests in California almonds are twig borer and navel orangeworm. Both pests can severely damage nut crop harvests if not controlled. Chlorpyrifos is used to control twig borer, navel orangeworm, and other insect pests including mites, leaffooted bug, San Jose scale, and ants.

Table 173. Target Pests in California Almonds – Pest Acres 2012-2014.

Insecticide	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
WORM, NAVEL ORANGE	1,227,899	1,541,390	1,747,434	1,505,574	33.3%
BORER, TWIG	1,036,230	1,106,735	1,305,961	1,149,642	25.5%
MITE, 2-SPOTTED	741,155	1,060,429	1,003,481	935,022	20.7%
MITE	290,071	733,012	381,963	468,348	10.4%
MITE, PACIFIC SPIDER	261,494	472,769	389,363	374,542	8.3%
MITE, SPIDER	251,520	168,571	389,413	269,835	6.0%
U.S. Total	**4,609,819**	**6,401,553**	**6,340,428**	**5,783,933**	**Column Total 104.1%**

Source: Proprietary third party data.

28.3.1.1 Navel Orangeworm

The navel orangeworm is the leading pest in almonds. The larvae feed directly on the nutmeats, making them unsuitable for the marketplace. Usually more than one larva can be found feeding in a nut. Navel orangeworm larval damage can also lead to fungal infections.

Chlorpyrifos was the seventh most-used active ingredients to control navel orangeworm, and was used on an average of 84,821 pest acres for navel orangeworm control in 2012-2014. Other insecticides used to control navel orangeworm include methoxyfenozide, bifenthrin, chlorantraniliprole, flubendiamide, lambda-cyhalothrin, and esfenvalerate. The cost per acre for chlorpyrifos for navel orangeworm control was $18.28, 14% less than the average per acre cost for all active ingredients ($21.15) for navel orangeworm control.

28.3.1.2 Peach Twig Borer

Peach twig borer larvae damage both growing shoots and nuts, causing shallow channels and surface grooves on the nutmeat. There can be as many as four generations of peach twig borer in a season. Chlorpyrifos was the eighth most-used active ingredients to control this insect pest, and was used on an average of 71,104 pest acres for peach twig borer control in 2012-2014. Other insecticides used to control peach twig borer include methoxyfenozide, esfenvalerate, chlorantraniliprole, lambda-cyhalothrin, bifenthrin, flubendiamide and diflubenzuron. The cost per acre for chlorpyrifos for peach twig borer control was $19.38, 8% higher than the average per acre cost for all active ingredients ($17.93) for peach twig borer control. The broad spectrum control of other insect pests by chlorpyrifos reduces the negative impact of this cost difference.

28.3.2 How Chlorpyrifos Is Used in Almonds

There are four key use patterns for chlorpyrifos to control pests in almonds: winter dormant sprays, May sprays for peach twig borer, hull-split sprays for peach twig borer and navel orangeworm, and ant control on the orchard floor. Although some use of chlorpyrifos occurs with each of these patterns annually, an individual orchard does not use all four spray timings to manage key pests. Chlorpyrifos is likely to be used in only one, or at most two applications per season in a given orchard.

Dormant sprays are typically applied during late December through the end of January, and are targeted at the overwintering generation of peach twig borer and San Jose scale. Air blast applications at 100 gallons per acre (GPA) are preferred, but if soils are saturated from winter rains, aerial applications at 10-20 GPA will occasionally be utilized. Chlorpyrifos is not registered to be applied for almonds by air as a dormant spray since the minimum spray volume is 100 GPA, and this cannot be achieved by air. Although not commonly used in dormant spray programs, when used, chlorpyrifos is applied at 2.0 lb a.i./A in combination with 2.0% dormant oil (v/v).

"May sprays" are targeted at first generation of peach twig borer, and to a lesser degree navel orangeworm. Some degree of benefit in worker ant suppression is also achieved through a May spray utilizing chlorpyrifos. Traditionally, products that do not harm beneficial arthropods are preferred for May sprays because their use does not flare spider mite populations in almonds. Chlorpyrifos is among those products that do not flare spidermites, making it a product of choice. The rate of 2.0 lb a.i./A of chlorpyrifos is applied at 100 GPA in an orchard airblast application. Orchards that received a dormant application typically do not receive a May spray.

Ant sprays with chlorpyrifos are not as common as they used to be two decades ago in almonds. Granular bait applications containing abamectin or pyriproxyfen are the primary products used. Chlorpyrifos is used only as a rescue treatment when the baits were not applied earlier in the season. Ants are direct pests of almonds, and consume the nutmeats as the nuts dry on the orchard floor following shaking and prior to sweeping. Chlorpyrifos is applied to the orchard floor at a rate of 2.0 to 4.0 lb a.i./A during the summer months prior to harvest to reduce worker ant activity. Applications are made either directed to the orchard floor with a broadcast boom sprayer modified for directed herbicide applications in orchards as a strip spray, as a total orchard floor spray, or through microjet sprinkler irrigation.

Hull-split applications are typically made just prior to and during the initial phase of the nut hull splitting open to expose the nutmeat. Peach twig borer and especially navel orangeworm can both feed directly on the nutmeats, causing considerable yield and quality losses. Typically one application at 2.0 lb a.i./A of chlorpyrifos is made at 1.0 – 5.0% hull split. In high population situations, a second application of an insecticide may be applied within 7 – 10 days. When a second application is required, typically a different product is used for resistance management reasons. Applications are made with orchard airblast sprayers utilizing 100 GPA. Pre-harvest interval, potential for mite outbreak, and residual are critical in the selection of the insecticide used for hull-split applications.

More than 70% of chlorpyrifos used in almonds occurs during the hull split or the application that occurs within 2-3 weeks of hull split. Chlorpyrifos is a preferred insecticide during this time frame due to its reliable control. This application is targeted primarily against navel orangeworm, and to a lesser extent peach twig borer. However, some ant suppression in the orchard floor is also achieved with this application.

Approximately 10% of chlorpyrifos used in almonds is used for ant control. Increasing ant populations and damaged nuts have driven continued use of chlorpyrifos for ant control.

Approximately 10% of total chlorpyrifos usage in almonds occurs in dormant applications. Chlorpyrifos as a dormant spray is used primarily when San Jose scale is a concern. This application will provide control of scale, peach twig borer, and overwintering mite eggs particularly when used in combination with supreme oil.

May sprays represent approximately 10% of the total chlorpyrifos applied in almonds. Methoxyfenozide, chlorantraniliprole, flubendiamide, and spinosad/spinetoram are favored active ingredients at this timing due to their safety to beneficial arthropods, and lack of mite flare. Pyrethroids are being increasingly applied for May sprays due to a very competitive cost position, however, concerns of mite flare have somewhat limited pyrethroid use in this timing.

28.3.3 Benefits of Chlorpyrifos in Almonds

- Important component of year-round pest management programs for navel orangeworm and peach twig borer, the two most important insect pests in almonds, as well as other economically important insect pests like ants and San Jose scale.
- Effective control of the overwintering generation peach twig borer and San Jose scale with dormant applications, effective control of peach twig borer with May sprays, effective control of peach twig borer and navel orangeworm with hull-split sprays,, and effective control of ants on the orchard floor.
- Broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Less harmful to beneficial populations than some alternatives, and does not flare mite populations.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.
- Cost effective.

28.3.4 Chlorpyrifos Formulations, Rates, and Applications

The formulations listed for treating almonds include Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, Cobalt, and Cobalt Advanced.

Location: CA

- Pests: overwintering generation of peach twig borer and San Jose scale
- Product: Lorsban-4E
- Application Type: airblast, aerial, dormant spray
- Application Method: airblast application at 100 GPA, if soil saturated by rain, aerial
- applications at 10-20 GPA may be utilized
- Rate: 2.0 lb a.i./A in combination with 2% dormant oil (v/v)
- Number of Applications: 1
- Season of Application: late December-end of January

Location: CA

- Pests: peach twig borer and navel orangeworm, some ant worker suppression
- Product: Lorsban-4E
- Application Type: spray
- Application Method: airblast application at 100 GPA, if soil saturated by rain, aerial applications at 10-20 GPA may be utilized
- Rate: 2.0 lb a.i./A in combination with 2% dormant oil (v/v)
- Number of Applications: 1
- Season of Application: May; orchards that receive a dormant application typically do not receive a "May spray"

Table 174. Leading Chemical Treatments for Insect Control in Almonds.

Note: Information in the "Benefits, Application, Use and Efficacy" section reflect opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Benefits, Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, others	-Broad spectrum insect pest control. -Does not harm beneficial arthropods; preferred for May sprays because use does not "flare" spider mite populations. -Used as "rescue" product when ant baits not applied earlier in season. -Group 1B MOA. -Cost effective.
Chlorpyrifos + Gamma-Cyhalothrin/ Chlorpyrifos + Lambda-Cyhalothrin	Cobalt/ Cobalt Advanced	-Broad spectrum of pest control. -Good rotational product. -Groups 1B and 3A MOA.

Active Ingredient	Brand Names	Benefits, Application, Use, and Efficacy
Bifenthrin	Capture, Brigade, others	-Superior efficacy and low cost. -Approx 1/3 cost of organophosphates. -Low cost is over-riding concerns of disruption of beneficial arthropods and known problems with secondary mite outbreaks. -Detections in sediments of surface water is an emerging issue and significant barrier to use. -Group 3A MOA.
Bacillus thuringiensis (Bt)	Several	-Primarily used as "bloom" spray. -Requires two applications with moderate levels of control. -Popular a few years ago, but have lost market share to diflubenzuron and methoxyfenozide as bloom time spray. -Inadequate residual for May spray and hull-split applications. -Somewhat less expensive per application than organophosphate, but requires two applications. -Group 11A MOA.
Chlorantraniliprole	Altacor	-May be used for dormant, delayed dormant and spring applications for peach twig border and hull split applications for navel orangeworm. -Group 28 MOA. -Relatively expensive.
Diflubenzuron	Dimilin	-Insect growth regulator. -Used for peach twig borer control during bloom. -Gained in popularity due to safety to bees, long residual and "free ride" with fungicides during bloom. -Group 15 MOA.
Flubendiamide	Belt	-May be used for dormant, delayed dormant and spring applications for peach twig border and hull split applications for navel orangeworm. -Group 28 MOA. -Relatively expensive.
Esfenvalerate	Asana	-Superior efficacy and low cost. -Approx 1/3 cost of organophosphates. -Low cost is over-riding concerns of disruption of beneficial arthropods and known problems with secondary mite outbreaks. -Detections in sediments of surface water is an emerging issue and significant barrier to use. -Group 3A MOA.
Lambda-Cyhalothrin	Warrior, others	-Superior efficacy and low cost. -Approx 1/3 cost of organophosphates. -Low cost is over-riding concerns of disruption

Active Ingredient	Brand Names	Benefits, Application, Use, and Efficacy
		of beneficial arthropods and known problems with secondary mite outbreaks. -Detections in sediments of surface water is an emerging issue and significant barrier to use. -Group 3A MOA.
Methoxyfenozide	Intrepid	-Gained in popularity for Lepidoptera insect control. -Used for peach twig borer during bloom; navel orange worm as May spray and for both peach twig borer and navel orangeworm during hull split and post hull split. -Bloom time application popular due to safety to bees, long residual and "free ride" with fungicides during bloom. -Group 18 MOA.
Petroleum Oil	Several	-High rates must be applied when used without an organophosphate. -Suppression rather than control. -Very good mixing partner for organophosphates.

28.3.5 Non-Chemical Alternatives

Mummy removal and early harvest are two main cultural practices for managing populations of navel orangeworm in almonds. The University of California Cooperative Extension and UC IPM area wide have successfully promoted and implemented these ideas over the years. Sanitation has been the key in keeping the navel orangeworm populations under manageable levels. Pheromone disruption has been under development for peach twig borer and navel orangeworm for some time, with no commercial successes in almonds.

Entomophagous nematodes – Parasitic nematodes have been evaluated both academically and commercially for control of Lepidoptera pests of almonds, especially peach twig borer and navel orangeworm. No consistent commercially acceptable control has been achieved by this means. In addition, commercially developed products based on entomophagous nematodes have been difficult to apply, have had poor shelf life, and have had a very high cost structure relative to standard insecticides.

28.4 <u>Walnuts</u>

A number of pests threaten California walnut crops including codling moth, walnut husk fly, spidermites, navel orangeworm, and walnut aphid. Chlorpyrifos is especially important to walnut growers, and is the leading active ingredient used for treating insect pests in walnut crops. An average of 205,961 active ingredient acres were treated annually with chlorpyrifos to control insect pests in 2012-2014.

Table 175. Leading Insecticide Active Ingredients Used in Walnuts – Acres Treated 2012–2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CHLORPYRIFOS	186,861	180,883	250,139	205,961	16.4%
ABAMECTIN	176,961	168,459	226,353	190,591	15.2%
BIFENTHRIN	100,149	129,627	106,110	111,962	8.9%
CHLORANTRANILIPROLE	66,682	82,829	119,898	89,803	7.2%
ACETAMIPRID	74,321	63,447	110,557	82,775	6.6%
IMIDACLOPRID	77,786	63,931	76,514	72,744	5.8%
U.S. Total	**1,144,220**	**1,100,806**	**1,520,893**	**1,255,306**	**Column Total 60.1%**

Source: Proprietary third party data.

Some variation in acres treated and lbs a.i. applied were found comparing CDPR and proprietary third party data for chlorpyrifos use in Walnuts.

Table 176. Chlorpyrifos Use in California Walnuts –Lb Acres Treated and A.I. Applied 2012-2014.

Walnuts	Data Source	2012	2013	2014	2012-2014 Average
Acres Treated	CDPR	95,631	89,436	100,076	95,048
	Third party proprietary	186,861	180,883	250,139	205,961
Lb a.i. Applied	CDPR	169,966	164,205	182,119	172,096
	Third party proprietary	344,137	344,272	487,857	392,089

28.4.1 Target Pests

The two primary pests in California walnuts are codling moth and husk fly. Both pests can severely damage nut crop harvests if not controlled. Chlorpyrifos is used to control codling moth, husk fly, and other insect pests including navel orangeworm and scale in walnuts.

Table 177. Top Pests in California Walnuts – Pest Acres 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
MOTH, CODLING	508,520	530,069	591,967	543,519	43.3%
FLY, HUSK	350,225	342,675	441,136	378,012	30.1%
MITE, 2-SPOTTED	217,002	153,244	286,474	218,906	17.4%
WORM, NAVEL ORANGE	82,506	101,013	126,853	103,457	8.2%
MITE, SPIDER	64,295	56,435	59,776	60,169	4.8%
MITE	25,886	61,892	81,587	56,455	4.5%
U.S. Total	**1,478,744**	**1,409,299**	**1,922,848**	**1,603,631**	**Column Total 108.4%**

Source: Proprietary third party data.

28.4.1.1 Codling Moth

Codling moth is the most serious pest of walnuts in California, and can greatly affect yields. Two to three generations of codling moth attack walnuts in California. First generation larvae cause nutlets to drop from the tree, and subsequent generations can damage the nut kernel making them unmarketable. Damaged kernels can also become breeding sites for the naval orangeworm, another crop-damaging pest.

Chlorpyrifos is the leading treatment for codling moth in California walnuts. Walnut growers used chlorpyrifos on an average of 142,582 pest acres (26.2% of total pest acres) annually to control codling moth in 2012-2014. Other insecticides used include chlorantraniliprole, bifenthrin, acetamiprid, lambda-cyhalothrin, esfenvalerate, and methoxyfenozide.

28.4.1.2 Walnut Husk Fly

The walnut husk fly infests walnuts in most California walnut-growing areas. Larvae feed in groups within the husk, but are not visible unless the skin of the damaged husk is removed. The primary damage from the husk fly is nutshell staining, which is a problem in commercial orchards where nuts are grown for in-shell sale. However, this can be tolerated in backyard situations. Feeding by the husk fly maggots also causes the damaged husks to stick to the shell, making them difficult to remove. An early season husk fly infestation (June to mid-August) can result in shriveled, moldy kernels.

Chlorpyrifos is the leading treatment for walnut husk fly in California walnuts, and plays an important role in integrated pest management. Walnut growers used chlorpyrifos on an average of 127,688 pest acres (33.8% of total pest acres) annually to control walnut husk fly in 2012-2014. Other insecticides used include acetamiprid, bifenthrin, imidacloprid, malathion, spinosad, and esfenvalerate.

28.4.2 How Chlorpyrifos Is Used in Walnuts

Chlorpyrifos is foliar applied to walnuts with an orchard airblast sprayer at 200 GPA. Three potential application windows are available for the use of chlorpyrifos for control of codling moth or walnut husk fly.

Chlorpyrifos is applied at 2.0 lb a.i./A in late April-mid May or early June targeted at codling moth. As mentioned above, two to three generations of codling moth attack walnuts in California and each generation is bimodal (i.e., two distinct population peaks are evident). The two populations present in the first generation are designated peaks 1A and 1B respectively, and peaks of the second generation are designated 2A and 2B.

The majority of chlorpyrifos use is targeted at the first generation. Applications targeted at peak 1A are applied when two conditions have been met. Nuts must be at least one half inch in diameter, and 250-300 degree days have accumulated following first trap capture of moths (known as the biofix). Applications for peak 1B are made at 650-700 degree days post biofix. These applications usually occur in May.

Second generation applications occur at 250-300 degree days post biofix for peak 2A, and 650-700 degree days post biofix for peak 2B. These applications typically occur in June and July.

Greater than 90% of current volume of chlorpyrifos used on walnuts is for management of codling moth, and nearly 70% of chlorpyrifos use for codling moth is for first generation (peaks 1A and 1B) cover sprays. Pyrethroids, chlorantraniliprole and methoxyfenozide are preferred for control of second generation codling moth.

In the late 1980s and early 1990s, chlorpyrifos rapidly displaced azinphos-methyl to become the preferred active ingredient for codling moth control in walnuts. This was primarily due to use for first generation codling moth cover sprays, and the short residual relative to azinphos-methyl. University of California researchers found that use of chlorpyrifos was compatible with biological control of walnut aphid allowing *Trioxys* sp., a parasitoid of the walnut aphid, to recolonize treated orchards for successful biological control of the aphid. If azinphos methyl was utilized for first generation codling moth, aphid flare-up would occur resulting in an additional application of insecticide.

In more recent years, chlorpyrifos market share has declined somewhat due to increased competitive pressures from pyrethroids (bifenthrin, esfenvalerate, and lambda-cyhalothrin), and the introduction of chlorantraniliprole and methoxyfenozide, a molting hormone mimic. Extended or bimodal peaks of the first and second generation codling moth flights have favored the use of more residual organophosphates and pyrethroids. Pyrethroids are considered highly disruptive to beneficial arthropod systems, but are used by growers due to low cost.

28.4.3 Benefits of Chlorpyrifos in Walnuts

- Chlorpyrifos is the insecticide most used for control of codling moth and walnut husk fly, the two top insect pests in walnuts.
- Effective control of the primary insect pests in walnuts including codling moth and walnut husk fly, as well as other economically important insect pests including navel orangeworm and scale.
- Provides broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Less harmful to beneficial populations than some alternatives, and does not flare aphid populations.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance.
- Cost effective.

28.4.4 Chlorpyrifos Formulations, Rates, and Applications

The formulations listed for controlling insect pests in walnuts include Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, Cobalt and Cobalt Advanced.

Location: CA
- Pests: codling moth
- Product: Lorsban-4E
- Application Type: airblast, aerial, dormant spray
- Application Method: airblast application at 200 GPA
- Rate: 2.0 lb a.i./A
- Season of Application: April-mid May or early June (first generation); June to July for second generation

Location: CA
- Pests: walnut husk fly
- Product: Lorsban-4E
- Application Type: airblast, aerial, dormant spray
- Application Method: airblast application at 200 GPA
- Rate: 2.0 lb a.i./A
- Season of Application: July-August

Table 178. Leading Chemical Treatments for Insect Control in Walnuts.

Note: Information in the "Benefits, Application, Use and Efficacy" section reflect opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, others	-Excellent control of first generation codling moth and husk fly. -Broad spectrum control of several pests. -Compatible with biological control of walnut aphid. -Group 1B MOA.
Chlorpyrifos + Gamma-Cyhalothrin/ Chlorpyrifos _ Lambda-Cyhalothrin	Cobalt/ Cobalt Advanced	-Broad spectrum of pest control. -Good rotational product. -Groups 1B and 3A MOA.
Bifenthrin	Capture, Brigade, others	-Excellent residual efficacy and costs approx. 1/2 of organophosphates. -Low cost is over-riding concerns of disruption of beneficial arthropods. -Detections in sediments of surface water is an emerging issue and significant barrier to use. -Group 3A MOA.
Chlorantraniliprole	Altacor	-Excellent codling moth control. -Does not control husk fly. -Relatively expensive. -Group 28 MOA.
Esfenvalerate	Asana	-Superior efficacy. -Cost approx. 1/3 cost of organophosphates. -Low cost is over-riding concerns of disruption of beneficial arthropods and known problems with secondary mite outbreaks. -Detections in sediments of surface water is an emerging issue and significant barrier to use. -Group 3A MOA.
Lambda-Cyhalothrin	Warrior, others	-Superior efficacy and cost approx. 1/3 cost of organophosphates. -Low cost is over-riding concerns of disruption of beneficial arthropods and known problems with secondary mite outbreaks. -Detections in sediments of surface water is an emerging issue and significant barrier to use. -Group 3A MOA.
Methoxyfenozide	Intrepid	-Used against 1B, 2A, 2B flights of codling moth. -Higher cost than chlorpyrifos. -Does not control walnut husk fly or walnut aphid. -Group 18 MOA.
Spinetoram	Delegate	-Excellent control of codling moth and husk fly. -Higher cost than chlorpyrifos.

Active Ingredient	Brand Names	Application, Use, and Efficacy
		-Group 6 MOA.

28.4.5 Non-Chemical Alternatives

Limited commercial successes have been achieved in walnuts with pheromone disruption. Trees abort any young nuts with injury; hence, a very low tolerance threshold must be maintained making pheromone viability questionable. Technologies for delivery systems have been studied extensively over the last two decades with limited success.

28.5 Pecans

A number of pests threaten pecan crops including pecan nut casebearer, black pecan aphid, pecan weevil, hickory shuckworm, and mites. Chlorpyrifos is especially important to pecan growers, and is the leading active ingredient used for treating insect pests in pecan crops. An average of 181,385 acres was treated annually with chlorpyrifos to control insect pests in pecans in 2012-2014.

Table 179. Leading Insecticide Active Ingredients Used in Pecans – Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CHLORPYRIFOS	205,921	162,045	176,190	181,385	20.8%
IMIDACLOPRID	131,011	153,954	157,427	147,464	16.9%
METHOXYFENOZIDE	85,370	96,148	106,115	95,878	11.0%
CYHALOTHRIN-LAMBDA	61,432	82,694	59,557	67,894	7.8%
CYPERMETHRIN	61,681	47,957	24,697	44,778	5.1%
BIFENTHRIN	23,458	17,495	77,829	39,594	4.5%
U.S. Total	**872,334**	**843,536**	**904,504**	**873,458**	**Column Total 66.1%**

Source: Proprietary third party data.

Growers used an average of 165,985 lb a.i. of chlorpyrifos annually to control insect pests in pecans in 2012-2014, a 44% decrease in average annual use from 2003-2007 (296,596 lb a.i.).

Table 180. Chlorpyrifos Use in Pecans –Lb Acres Treated and A.I. Applied 2012-2014.

Walnuts	2012	2013	2014	2012-2014 Average
Acres Treated	205,921	162,045	176,190	181,385
Lb a.i. Applied	205,087	127,474	165,395	165,985

Source: Proprietary third party data.

28.5.1 Target Pests

The two most important and widely distributed insect pests in pecans are pecan nut casebearer and black pecan aphid. Chlorpyrifos is used to control pecan nut casebearer, black pecan aphid, and other insect pests including pecan weevil, yellow pecan aphids, and hickory shuckworm.

Table 181. Top Pests in Pecans – Pest Acres 2012-2014.

Insecticide	Pest Acres				Average % of Total Pest Acres
	2012	2013	2014	2012-2014 Average	
CASEBEARER, PECAN NUT	234,615	257,300	225,227	239,047	20.9%
APHID, BLACK PECAN	172,653	182,408	180,889	178,650	15.6%
WEEVIL, PECAN	161,489	99,877	133,379	131,582	11.5%
APHID, YELLOW PECAN	114,830	113,311	114,987	114,376	10.0%
MITE	59,365	61,978	111,686	77,677	6.8%
SHUCKWORM, HICKORY	53,674	67,373	95,478	72,175	6.3%
U.S. Total	**1,101,783**	**1,148,304**	**1,188,019**	**1,146,035**	**Column Total 71.0%**

Source: Proprietary third party data.

28.5.1.1 Pecan Nut Casebearer

The pecan nut casebearer is the most damaging insect pest of pecans in Texas. Most of the damage is caused by first generation larvae feeding in the young nuts in late May and early June. Due to the small size of the nuts, each larva feeds in several nuts to complete its development. A larva often destroys an entire nut cluster. Second generation larvae do similar damage, but usually each larva only damages one nut. Overwintered larvae cause a certain amount of damage by tunneling and killing new shoots early in the spring [2].

Chlorpyrifos is the leading insecticide active ingredient for pecan nut casebearer control. Pecan growers used chlorpyrifos on an average of 89,951 pest acres (37.6% of total pest acres) annually to control casebearer in 2012-2014. Other insecticides used include methoxyfenozide, imidacloprid, tebufenozide, diflubenzuron, and esfenvalerate.

28.5.1.2 Black Pecan Aphid

Black pecan aphids can significantly reduce pecan yields. The aphids suck photosynthates from leaves, excrete honeydew, and reduce the flow of nutrients to nuts. Black aphid damage is characterized by small, chlorotic areas on the leaflets. Heavy infestations cause rapid leaf shed. These aphids can cause premature leaf shed, reduced nut quality, and subsequent yield reductions the following season [3].

Chlorpyrifos is the second most-used insecticide active ingredient for black pecan aphid control. Pecan growers used chlorpyrifos on an average of 839,584 pest acres (22.2% of total pest acres) annually to control black pecan aphid in 2012-2014. Other insecticides used include imidacloprid, sulfoxaflor, bifenthrin, pyridaben, and cypermethrin.

28.5.1.3 Other Insect Pests

Chlorpyrifos is also used to control pecan weevil, yellow pecan aphids, and hickory shuckworm.

28.5.2 How Chlorpyrifos Is Used in Pecans

Chlorpyrifos is foliar-applied to pecans with an orchard airblast sprayer at 200-400 GPA. Three potential application windows are available for the use of chlorpyrifos for control of aphids, hickory nut shuckworm, pecan casebearer, and others. Chlorpyrifos will generally account for 1 to 2 applications per season on pecan groves targeted against pecan nut casebearer, black pecan aphid, hickory shuckworm, *Phylloxera,* spittlebugs and/or the yellow aphid complex. Use pattern depends on pest history of plantation. Insecticide sprays are generally combined with a scab fungicide program. Most applications are ground applied with an airblast sprayer. Aerial application does occur, but is of minor use.

28.5.3 Benefits of Chlorpyrifos in Pecans

- Chlorpyrifos is the insecticide most used to control pecan nut casebearer and black pecan aphid, the two top insect pests in pecans.
- Effective control of primary insect pests in pecans including pecan nut casebearer, black pecan aphid, pecan weevil, yellow pecan aphid, and hickory shuckworm as well as many other economic insect pests.
- Fast knockdown of aphids – superior aphid control compared to pyrethroids, which provide slower control and may allow aphid populations to rebuild following treatment.
- Broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Less harmful to beneficial populations than some alternatives, and does not flare mite or aphid populations – early season use of chlorpyrifos minimizes aphid and mite flare-up associated with other products, especially pyrethroids.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance. Pyrethroids (Group 3A) are used extensively because they are inexpensive and broad spectrum. The availability of chlorpyrifos allows growers to rotate between different insecticide modes of action, which helps delay resistance development in all insecticides. Resistance development to pyrethroids would proceed at an accelerated rate in the absence of chlorpyrifos.
- Cost effective.

28.5.4 Chlorpyrifos Formulations, Rates, and Applications

The formulations listed for controlling pests in pecans include Lorsban-4E (and other 4 lbs per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, Cobalt and Cobalt Advanced.

Pest: black pecan aphid

- Application Rate: 1.0 lb a.i./A Lorsban-4E or 0.5 lb. a.i./A Lorsban-4E + pyrethroid.
- Timing: after July 1 when threshold reached

Pest: hickory shuckworm

- Application Rate: 1.0 lb a.i./A
- Timing: August

Pest: *Phylloxera* (sap eating root louse)

- Application Rate: 1.0 lb a.i./A
- Timing: at bud break

Pest: pecan nut casebearer

- Application Rate: 0.75-1.0 lb a.i./A (1st generation); 0.5 lb. a.i./A (2nd generation)
- Timing: April for 1st generation egg hatch; June for 2nd generation egg hatch

Pest: spittlebugs (SE U.S.)

- Rate: 0.75 lb a.i./A
- Timing: applied May through June
- Applications: 2 applications may be needed

Pest: yellow aphid complex

- Application Rate: 0.5 lb a.i./A Lorsban-4E + pyrethroid
- Timing: after July 1 when threshold reached

Table 182. Leading Chemical Treatments for Insect Control in Pecans.

Note: Information in the "Benefits, Application, Use and Efficacy" section reflect opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, others	-Broad spectrum control of pecan pest complex. -Fast knockdown. -Early season use minimizes aphid and mite flare-up associated with other products, especially pyrethroids. -Group 1B MOA
Chlorpyrifos + Gamma-	Cobalt/	-Broad spectrum control of pecan pest complex.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Cyhalothrin	Cobalt Advanced	-Good knockdown and residual control. -Groups 1B and 3A MOA.
Bifenthrin	Capture, Brigade, others	-Excellent residual efficacy and cost approx. 1/2 cost of organophosphates. -Low cost is overriding concerns of disruption of beneficial arthropods and known problems with secondary mite outbreaks. -Early season sprays for pecan nut casebearer have historically resulted in severe mite and aphid problems later resulting in limited use. -Shuckworm applications occur later in season, so mite flare is of lower concern. -Group 3A MOA.
Esfenvalerate	Asana	-Excellent residual efficacy and cost approx. 1/2 cost of organophosphates. -Low cost is overriding concerns of disruption of beneficial arthropods and known problems with secondary mite outbreaks. -Early season sprays for pecan nut casebearer have historically resulted in severe mite and aphid problems later resulting in limited use. -Shuckworm applications occur later in season, so mite flare is of lower concern. -Group 3A MOA.
Imidacloprid	Several	-Excellent aphid control. -Translocated within the plant, which can compensate for poor application. -Control limited to *Homopteran* and *Hemipteran* insects. -Group 4A MOA.
Lambda-cyhalothrin	Warrior, others	-Excellent residual efficacy and cost approx. 1/2 cost of organophosphates. -Low cost is overriding concerns of disruption of beneficial arthropods and known problems with secondary mite outbreaks. -Early season sprays for pecan nut casebearer have historically resulted in severe mite and aphid problems later resulting in limited use. -Shuckworm applications occur later in season, so mite flare is of lower concern. -Group 3A MOA.
Methoxyfenozide	Intrepid	-Controls pecan nut casebearer and hickory shuckworm. -Does not control aphids. -Group 18 MOA.

28.5.5 Non-Chemical Alternatives

There are currently no viable non-chemical alternatives available.

28.5.6 Grower Perspective

The following is an excerpt from a university specialist who responded to the EPA's request for input by explaining why chlorpyrifos is considered essential for protecting crops. Submissions to the docket are public information, and have been posted by the EPA at www.regulations.gov, docket number EPA-HQOPP- 2007-1005. Growers also commented during public comment periods in 2011 (EPA-HQ-OPP-2008-0850-0025) and 2015 (EPA-HQ-OPP-0850-0224).

"My major concerns regarding the withdrawal of chlorpyrifos from the management options currently available to pecan growers in Texas are 1) that the risk of resistance to remaining materials will increase; 2) that some producers may adopt materials that are more disruptive of the IPM [Integrated Pest Management] program (i.e., pyrethroids) than those currently being used; and 3) that outbreaks of secondary pests like aphids, mites and leafminers may result and trigger more insecticide use than is currently needed to produce large crops of good quality." – Texas Entomologist

28.6 References

1. U.S. Department of Agriculture, Economic Research Service. *Fruit and Nut Trees Background.* May 26, 2012. http://www.ers.usda.gov/Briefing/FruitandTreeNuts/Background.htm. Accessed December 10, 2015.
2. Oklahoma State University, Entomology and Plant Pathology. *Pecan Nut Casebearer.* http://entoweb.okstate.edu/ddd/insects/pecannutcasebearer.htm. Accessed December 10, 2015.
3. Texas A & M University, Department of Entomology. *Pecan Insect Pests.* http://pecankernel.tamu.edu/pecan_insects/pests/#black. Accessed December 10, 2015.

29. Wheat

29.1 Overview

The U.S. is a major wheat-producing country, with output typically exceeded only by China, the European Union, and India. Wheat ranks third among U.S. field crops in both planted acreage and gross farm receipts, behind corn and soybeans. Presently, about half of the U.S. wheat crop is exported [1]. Wheat is the main food grain produced in the U.S. Wheat varieties grown in the U.S. are classified as "winter wheat" or "spring wheat," depending on the season in which each is planted. Approximately 75% of the total wheat grown in the U.S. is winter wheat. Approximately 84% of wheat acres were planted in the Plains and West regions in 2012-2014. Five states, Kansas, North Dakota, Texas, Oklahoma, and Montana accounted for 63% of planted acres in 2012-2014.

Table 183. U.S. Wheat Planted Acres – 2012-2014.

Region[1,2,3]	Acres Planted (000)			
	2012	**2013**	**2014**	**2012-2014 Average**
Atlantic	672	1,089	758	840
Midwest	4,625	5,010	4,840	4825
Plains	32,408	31,638	32,493	32180
South	2,980	3,460	3,050	3,163
West	13,625	13,150	14,254	13,676
Total U.S.	**54,310**	**54,347**	**55,396**	**54,684**

[1] USDA Farm Production Regions.
[2] Source for Atlantic region: USDA, NASS.
[3] Source for Midwest, Plains, South and West regions: Proprietary third party data.

29.2 Chlorpyrifos Use

Chlorpyrifos is approved for use in wheat in states west of the Mississippi only. Chlorpyrifos was used on an average of 1,573,461 acres of wheat annually, and was the second most-used insecticide active ingredient in 2012-2014.

Table 184. Leading Insecticide Active Ingredients Used in Wheat – Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Acres Treated (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CYHALOTHRIN-LAMBDA	3,133,556	3,301,272	2,700,273	3,045,034	48.4%
CHLORPYRIFOS	1,376,425	1,588,334	1,755,623	1,573,461	25.0%
CYFLUTHRIN	501,171	397,931	666,540	521,881	8.3%
ZETA-CYPERMETHRIN	467,059	420,329	407,257	431,549	6.9%
DIMETHOATE	355,242	87,052	375,652	272,649	4.3%
U.S. Total	**6,013,294**	**6,293,768**	**6,557,043**	**6,013,294**	**Column Total 92.9%**

Source: Proprietary third party data. Excluding seed treatments.

Growers used an average of 614,730 lb a.i. of chlorpyrifos annually to control insect pests in wheat in 2012-2014, more than twice the average annual use in 2003-2007 (288,571 lb a.i.). Approximately half of the chlorpyrifos was applied to spring wheat and the other half to winter wheat.

Table 185. Chlorpyrifos Use in Wheat – Acres Treated and Lb. a.i. Applied 2012-2014.

Chlorpyrifos	2012	2013	2014	2012-2014 Average
Acres Treated	1,376,425	1,588,334	1,755,623	1,573,461
Lb a.i. Applied	570,362	664,483	609,344	614,730

Source: Proprietary third party data.

The Plains region accounted for over 90% of total U.S. chlorpyrifos treated acres and lbs a.i. applied in 2012-2014. Chlorpyrifos was the leading insecticide active ingredient used, and accounted for 49.7% of active ingredient treated acres in the Plains region in 2012-2014.

Table 186. Leading Insecticide Active Ingredients Used in the Plains Region on Wheat – Acres Treated 2012-2014.

Insecticide	Acres Treated				% of Total a.i. Acres Treated (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CHLORPYRIFOS	1,264,767	1,367,310	1,657,989	1,430,022	49.7%
CYHALOTHRIN-LAMBDA	1,358,399	765,669	811,815	978,628	34.0%
CYFLUTHRIN	222,717	183,838	70,863	159,139	5.5%
ZETA-CYPERMETHRIN	334,371	29,361	8,767	124,167	4.3%
DIMETHOATE	284,463	--	--	94,821	3.3%
U.S. Total	**3,506,196**	**2,368,300**	**2,749,606**	**2,874,700**	Column Total **96.9%**

Source: Proprietary third party data. Excluding seed treatments.

Chlorpyrifos was the leading active ingredient in North Dakota, Oklahoma and Texas comprising 95.4%, 94.8% and 82.7% of the active ingredient applications applied in these states, respectively, in 2012-2014.

29.3 Target Pests

Aphids, wheat midge, cereal leaf beetle, armyworm, mites and grasshoppers were the top target pests in wheat, and accounted for 71.1% of the total active ingredient acres. Chlorpyrifos provides broad spectrum control of a number of insect pests in wheat, and was primarily used to control aphids, wheat midge, mites, and grasshoppers in 2012-2014.

Table 187. Top Insect Pests in Wheat – Pest Acres 2012-2014.

Insect	Pest Acres				% of Total a.i. Treated Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
APHID	1,307,392	2,706,408	2,023,609	2,012,470	32.0%
MIDGE, WHEAT	450,452	644,376	474,834	523,221	8.3%
BEETLE, CEREAL LEAF	466,033	495,859	470,927	477,606	7.6%
ARMYWORM	360,681	438,200	390,234	396,372	6.3%
MITE, BROWN WHEAT	134,195	110,122	929,240	391,186	6.2%
APHID, BIRD CHERRY-OAT	119,475	703,067	197,415	339,985	5.4%
GRASSHOPPER	234,964	553,783	203,860	330,869	5.3%
U.S. Total	**7,626,888**	**8,044,554**	**7,915,333**	**7,862,258**	Column Total **71.1%**

Source: Proprietary third party data. Excluding seed treatments.

29.3.1 Aphids

Aphids (greenbug, Russian wheat aphids, green peach aphids, and bird cherry-oak aphids) are the most troublesome insect pests in wheat in the U.S., and can inflict substantial losses. An average of over 3.0 million active ingredient treated acres, 38.2% of the total active ingredient treated acres used in wheat, were applied annually to control greenbug, Russian wheat aphid, and other aphids in 2012-2014.

Chlorpyrifos and lambda-cyhalothrin are the leading insecticides used to control aphids in wheat. Cyfluthrin, zeta cypermethrin, and dimethoate were also used. Chlorpyrifos accounted for 35.4% of all pest acres treated for aphids in wheat, and was the leading product applied for aphid control in 2012 and 2014. Chlorpyrifos provides fast knockdown of aphids which are known for explosive population growth, and is the only active ingredient that can effectively control Russian wheat aphid after they are protected inside of rolled up wheat leaves in later colonization stages.

Table 188. Leading Active Ingredients Used to Control Aphids in Wheat – Pest Acres 2012-2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CYHALOTHRIN-LAMBDA	800,356	1,955,960	843,006	1,199,774	39.9%
CHLORPYRIFOS	1,192,233	1,110,458	893,619	1,065,437	35.4%
CYFLUTHRIN	105,790	225,298	306,562	212,550	7.1%
ZETA-CYPERMETHRIN	305,593	58,925	122,210	162,243	5.4%
DIMETHOATE	106,471	39,645	175,453	107,190	3.6%
U.S. Total	**2,599,164**	**3,798,055**	**2,627,587**	**3,008,269**	**Column Total 91.3%**

Source: Proprietary third party data. Excluding seed treatments.

29.3.2 Wheat Midge

The wheat midge (orange blossom wheat midge) is a very devastating pest which primarily infests spring wheat. The wheat midge is a seed feeder, and infests a wheat plant during heading through early flowering. Wheat midge larvae feed on the developing wheat kernel by exuding enzymes that break down cell walls, and convert starch to simple sugars. This causes the wheat kernel to shrivel, crack, and become deformed. Wheat kernels may be partially damaged or entirely aborted. Economic damage caused by the wheat midge reduces yield, grain quality, germination, and growth vigor of seedlings. The presence of wheat midge larvae in stored wheat grain may cause heating in the grain bins, and eventually contaminate flour milled from infested grain. Wheat midge adults can act as a vector for microorganisms that infect wheat seeds (wheat scab and glume blotch).

Chlorpyrifos was, by far, the leading insecticide active ingredient used to control wheat midge in 2012-2014.

Table 189. Leading Active Ingredients Used to Control Wheat Midge in Wheat – Pest Acres 2012-2014.

Insecticide	Pest Acres				% of Total Pest Acres (2012-2014 Average)
	2012	2013	2014	2012-2014 Average	
CHLORPYRIFOS	404,129	483,706	471,523	453,119	74.5%
CYHALOTHRIN-LAMBDA	101,341	149,150	191,626	147,372	24.2%
CYFLUTHRIN	23,271	--	--	7,757	1.3%
U.S. Total	**528,741**	**632,856**	**663,149**	**608,249**	**Column Total 100.0%**

Source: Proprietary third party data. Excluding seed treatments.

29.3.3 Other Insect Pests

Chlorpyrifos is also used to control other target pests in wheat including grasshoppers, armyworm, mites (brown wheat, spider), and orange wheat blossom midge.

29.4 Cost of Treatment

The average cost per acre for chlorpyrifos and lambda-cyhalothrin, the two leading insecticides used in wheat, was $3.08 and $3.23 per acre, respectively, in 2014. Chlorpyrifos had the lowest cost among the top five insecticide active ingredients used in wheat, and was 10% less than the average per acre insecticide cost ($3.43 per acre).

Table 190. Leading Insecticides Used in Wheat –Cost Per Acre 2014.

Insecticide	2014 Average Cost per Acre
DIMETHOATE	$4.33
CYFLUTHRIN	$3.80
ZETA-CYPERMETHRIN	$3.49
CYHALOTHRIN-LAMBDA	$3.23
CHLORPYRIFOS	$3.08
U.S. Average	$3.43

Source: Proprietary third party data.

29.5 Benefits of Chlorpyrifos in Wheat

- Chlorpyrifos is the insecticide most used to control wheat midge, and the second leading insecticide active ingredient used to control aphids.
- Effective control of the primary insect pests in wheat including aphids, wheat midge, mites, and grasshoppers as well as many other economically important insect pests like armyworm, cutworm, and leaf hoppers.
- Fast knockdown of aphids and other pests – superior aphid control compared to lambda-cyhalothrin and other pyrethroids, which provide slower control and may allow aphid populations to rebuild following treatment.
- Provides broad spectrum insect control in a single application, which helps reduce the number of insecticide applications necessary to control multiple pests.
- Effective rotation partner to manage insect resistance – offers a Group 1B mode of action to help manage resistance. Pyrethroids (Group 3) are used extensively because they are inexpensive and broad spectrum. The availability of chlorpyrifos allows growers to rotate between different insecticide modes of action, which helps delay resistance development in all insecticides. Resistance development to pyrethroids would proceed at an accelerated rate in the absence of chlorpyrifos.
- Cost effective.

29.6 Chlorpyrifos Formulations, Rates, and Applications

Formulations listed for controlling insect pests in wheat include Lorsban-4E (and other 4 lb per gallon EC formulations of chlorpyrifos), Lorsban Advanced, Lorsban 75WG, Cobalt, and Cobalt Advanced.

Location: TX

- Pests: greenbugs (aphid), mites (brown wheat, spider)
- Application Type: foliar ground
- Application Method: boom sprayer
- Rate: 0.375 lb a.i./A
- Number of Applications: 1-2
- Timing of Application: December-February

Location: ND, MT, MN

- Pests: aphid, cereal leaf beetle, grasshopper, armyworm, orange wheat blossom midge
- Application Type: foliar, ground and aerial
- Application Method: broadcast
- Rate: 0.25-0.5 lb a.i./A
- Number of Applications: 1-2
- Timing of Application: Spring/Summer

Location: OK, KS, CO

- Pests: aphids, greenbug, mites (brown wheat, spider)
- Application Type: foliar, ground, chemigation
- Application Method: broadcast
- Rate: 0.25-0.5 lb a.i./A
- Number of Applications: 1
- Timing of Application: Spring

Table 191. Leading Chemical Treatments for Insect Control in Wheat.

Note: Information in the "Benefits, Application, Use and Efficacy" section reflect opinions of crop consultants, field experts, and other contributors to this report.

Active Ingredient	Brand Names	Application, Use, and Efficacy
Chlorpyrifos	Lorsban Advanced, Lorsban-4E, Lorsban 75WG, others	-Controls aphids, wheat midge, mites, grasshoppers and other insect pests. -Control of aphids, including Russian wheat aphid, and wheat midge is superior to the pyrethroids. -Broad spectrum. -Fast knockdown. -Group 1B MOA for resistance management -Cost-effective.
Chlorpyrifos + Gamma-Cyhalothrin/ Chlorpyrifos + Lambda-Cyhalothrin	Cobalt/ Cobalt Advanced	-Controls aphids, wheat midge, mites, grasshoppers and other insect pests. -Control of aphids, including Russian wheat aphid, and wheat midge is superior to the pyrethroids. -Broad spectrum. -Fast knockdown. -Groups 1B and 3 MOA for resistance management -Cost-effective
Cyfluthrin	Baythroid, others	-Second-tier aphid product. -Suppression of greenbug. -Group 3A MOA.
Gamma-Cyhalothrin	Proaxis, others	-Second-tier aphid product. -Suppression of greenbug. -Group 3A MOA.
Lambda-Cyhalothrin	Warrior, Karate, others	-Provides the most consistent control among the pyrethroids. -Second-tier aphid product. -Slower knockdown which may allow aphid populations to rebuild following treatment. -Group 3A MOA.
Zeta-Cypermethrin	Mustang, others	-Second-tier aphid product -Suppression of greenbug. -Group 3A MOA.

29.7 Non-Chemical Alternatives

There are currently no practical non-chemical control alternatives effective for management of aphids and midge in wheat.

29.8 Grower Perspective

In late 2007, the EPA asked for public comments on issues related to the agricultural use of chlorpyrifos. The following is an excerpt from a grower who responded to the EPA's request for input by explaining why he considered chlorpyrifos essential for protecting his crops. Submissions to the docket are public information and have been posted by the EPA at www.regulations.gov, docket number EPA-HQ-OPP-2007-1005. Growers also commented during public comment periods in 2011 (EPA-HQ-OPP-2008-0850-0025) and 2015 (EPA-HQ-OPP-0850-0224).

"On wheat, chlorpyrifos at low rates provides a reasonable control method for an outbreak of Russian wheat aphid. Aphids can cause significant damage to wheat on our farm by reducing both yield and quality." – North Dakota grower

29.9 References

1. United States Department of Agriculture, Economic Research Services. August 27, 2015. http://www.ers.usda.gov/Briefing/Wheat/. Accessed December 9, 2015.
2. North Dakota State University Extension. *Integrated Management of the Wheat Midge in North Dakota E-1330*. 2008. https://www.ag.ndsu.edu/pubs/plantsci/pests/e1330.pdf. Accessed January 3, 2016.