# California Citrus Pest Management Survey: A Summary of Responses

By

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## Introduction

Based on the results of a survey of citrus growers, this project investigates the use of beneficial insects among citrus growers and analyzes the effects of landscape-level pesticide use on the presence and use of these beneficial insects. We focus on predators or parasitoids (known collectively as natural enemies) of four major citrus pests.

*Aphytis melinus*, a parasitic wasp, lays its eggs in the California red scale, a primary citrus pest in the San Joaquin Valley, the Coastal-Intermediate Region, and the Interior Region. When the wasp's eggs hatch, the larvae eat the scale, and the scale dies. The wasp is produced by commercial insectaries and can be purchased and released by growers to control the California red scale. However, carbaryl (Sevin™), chlorpyrifos (Lorsban™), and methidathion (Supracide™), pesticides used to treat red scale and a variety of other citrus pests, and acetamiprid (Assail™), cyfluthrin (Baythroid™), and fenpropathrin (Danitol™), pesticides used to treat citrus pests other than red scale, are toxic to the wasp (Grafton-Cardwell 2009, 2010). All of these pesticides are also used on non-citrus crops (CDPR PUR 2004-2009), and *Aphytis melinus* also provides control of pests of non-citrus crops.

A predatory mite, *Euseius tularensis*, aids in control of citrus red mite and citrus thrips. Citrus red mite is a primary pest in the San Joaquin Valley and the Interior Region and a secondary pest in the Desert Region. Citrus thrips is a primary pest in all of California's growing regions. Unlike *Aphytis melinus*, *Euseius tularensis* is not commercially available (Weeden et al. 2007). The predacious mite is susceptible to four pesticides used to treat citrus pests. Cyfluthrin and fenpropathrin are used primarily for thrips control. Dimethoate and formetanate hydrochloride (Carzol™) are used to treat thrips as well as a variety of other citrus pests (UC IPM 2009a). Like the pesticides that are toxic to *Aphytis melinus*, all of the pesticides that are toxic to *Euseius tularensis* are also used on a variety of non-citrus crops, and *Euseius tularensis* predates pests of non-citrus crops as well.

Perhaps the most interesting citrus pest predator is *Rodolia cardinalis*, commonly known as the vedalia beetle. In the late 1800s, the cottony cushion scale, an invasive pest, threatened to eliminate the entire California citrus industry. Entomologists went to Australia, the origin of the cottony cushion scale, to find its natural enemies. In the winter of 1888-1889, the vedalia beetle was brought back to California and released, and the cottony cushion scale was under full control by the beetle in the areas of release by the fall of 1889 (Weeden et al. 2007). The beetle spread throughout the citrus growing regions and provided complete control of the cottony cushion scale until recent years when several pesticides proved toxic to the beetle, including cyfluthrin, fenpropathrin, acetamiprid, and imidacloprid, as well as buprofezin (Applaud™) and pyriproxifen (Esteem™), new insect growth regulators used for red scale control (Grafton-Cardwell 2005, UC IPM 2009b). The only effective pesticides available to treat the cottony cushion scale are conventional organophosphates (UCCE 2003), so organic growers and conventional growers following an integrated pest management program are dependent on control by the beetle. However, the use of pesticides that are toxic to the beetle results in beetle population kill-offs not only on the

treated field but also on the adjacent fields, most likely due to the highly mobile nature of the beetle (Weeden et al. 2007). Currently, vedalia beetles are not commercially available, so organic or IPM-based growers facing diminished beetle populations must either suffer crop damage from the scale or seek out beetles on other farms in unaffected areas to collect and release in their own fields (Weeden et al. 2007). Non-citrus growers also apply pesticides that are toxic to the beetle, but the beetle only consumes the cottony cushion scale, which is only a pest of citrus and a few varieties of Asian ornamental trees and shrubs (Dreistadt 2011; UC IPM 2009b).

The mobility of insects potentially allows nearby growers to affect each other through their pest control decisions. This project analyzes how landscape-level pesticide use affects the presence of beneficial insects and growers' pest control decisions. We find that the use of certain pesticides does impede the presence and use of beneficial insects on nearby fields, and we find that, in some cases, pesticides applied on non-citrus fields negatively affect beneficial insects on citrus fields.

**Survey and Project Design**

We obtained citrus grower addresses from eighteen county agricultural commissioner's offices (each county's percentage of total California citrus acreage is in parentheses): Butte (0.1%), Fresno (13.7%), Glenn (0.1%), Imperial (2.1%), Kern (22.2%), Kings (0.1%), Los Angeles (0.1%), Madera (1.8%), Orange (0.2%), Riverside (8.2%), San Bernardino (0.9%), San Diego (5.6%), San Joaquin (<0.1%), San Luis Obispo (0.7%), Santa Barbara (0.6%), Stanislaus (0.2%), Tulare (32.8%), and Ventura (10.0%) counties. These counties contain 99.1% of California citrus acreage (USDA 2007a). These counties represent the five citrus growing regions in California. The regions include the San Joaquin Valley Region, the Coastal-Intermediate Region (coastal regions from San Luis Obispo county to the San Diego-Mexico border), the Interior Region (western Riverside county; inland San Diego, Orange, and Los Angeles counties; and San Bernardino county), the Desert Region (Coachella and Imperial Valleys), and the Northern Region (Glenn and Butte counties).

The survey was mailed on March 18, 2010 to 3,959 growers, and a reminder postcard was mailed on April 15, 2010. Of this number, 348 surveys and an additional 28 postcards were undeliverable.[1] Another 88 surveys were mailed to people who responded that they did not produce citrus, no longer produced citrus, were in the citrus industry but had no acreage, or had less than an acre of citrus production for personal use. Additionally, information for 15 growers was included on other forms by farm managers who consolidated all managed acreage onto one survey form. Given the above, 3,480 surveys were mailed to individuals who presumably had citrus production in 2009 and could have responded. Of these, 429 growers did respond by June 3, 2010, resulting in a 12.3% response rate. 3.7% of

[1] Postcards were returned for addresses for which the surveys were also returned after the postcard mailing, but these are not included here to avoid counting these addresses twice. The 28 returned postcards corresponded to addresses to which the survey was presumably delivered.

respondents are from the Northern Region, 35.9% from the San Joaquin Valley, 51.0% from the Coastal-Intermediate Region, 7.9% from the Interior Region, and 1.4% from the Desert Region.

## Summary of Survey Responses

The survey begins by asking growers about the size of their citrus production and the acreage of other crops grown. Not surprisingly, orange production is the largest portion of reported acreage (Table 1a). Respondent acreages of lemons, mandarins, and grapefruits are second, third, and fourth, respectively. Limes make up the majority of "other" acreage.

**Table 1a. Summary Statistics of Respondents' Reported Citrus Acreage (422 Respondents Reported Acreage)**

| Variety | Average Reported Acres | Standard Deviation | Minimum | Maximum | Total Reported Acres |
|---|---|---|---|---|---|
| Conventional | | | | | |
| Orange | 50.7 | 245.5 | 0.0 | 3,800.0 | 21,363.9 |
| Lemon | 16.1 | 105.3 | 0.0 | 1,868.0 | 6,781.0 |
| Mandarins | 7.7 | 75.7 | 0.0 | 1,350.0 | 3,228.1 |
| Grapefruit | 2.7 | 23.3 | 0.0 | 450.0 | 1,145.5 |
| Tangelos | 1.7 | 25.0 | 0.0 | 500.0 | 704.2 |
| Tangors | 0.0 | 0.8 | 0.0 | 17.0 | 17.2 |
| Other | 0.4 | 2.6 | 0.0 | 40.0 | 184.6 |
| Certified Organic | | | | | |
| Orange | 0.8 | 4.7 | 0.0 | 60.0 | 321.5 |
| Lemon | 0.4 | 3.5 | 0.0 | 52.4 | 160.2 |
| Mandarins | 0.2 | 2.0 | 0.0 | 40.0 | 66.9 |
| Grapefruit | 0.3 | 3.4 | 0.0 | 68.0 | 125.1 |
| Tangelos | 0.0 | 0.2 | 0.0 | 3.0 | 7.3 |
| Tangors | 0.0 | 0.0 | 0.0 | 2.0 | 2.0 |
| Other | 0.0 | 0.2 | 0.0 | 3.5 | 4.5 |
| Total | | | | | 34,112.0 |

The acreage varies by crop region and crop type (Table 1b). The majority of total reported acreage and reported acreages of oranges, mandarins, and tangelos is located in the San Joaquin Valley. The majority of reported lemon acreage is located in the Coastal-Intermediate Region, and the majority of reported grapefruit acreage is located in the Interior Region.

**Table 1b. Summary Statistics of Respondents' Reported Citrus Acreage by Growing Region (422 Respondents Reported Acreage)**

| | Northern | | San Joaquin Valley | | Coastal | | Interior | | Desert | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variety | Average Reported Acres | Total Reported Acres | Average Reported Acres | Total Reported Acres | Average Reported Acres | Total Reported Acres | Average Reported Acres | Total Reported Acres | Average Reported Acres | Total Reported Acres |
| Conventional | | | | | | | | | | |
| Orange | 4.3 | 68.1 | 123.8 | 17948.8 | 9.2 | 2012.8 | 38.5 | 1309.2 | 0.0 | 0.0 |
| Lemon | 0.0 | 0.2 | 7.0 | 1010.8 | 25.5 | 5581.1 | 0.2 | 6.0 | 41.6 | 183.0 |
| Mandarins | 2.1 | 34.2 | 18.6 | 2693.16 | 2.4 | 519.5 | 0.3 | 9.0 | 3.3 | 20.0 |
| Grapefruit | 0.1 | 1.3 | 2.6 | 376.3 | 0.8 | 180.9 | 17.1 | 583.0 | 0.0 | 0.0 |
| Tangelos | 0.0 | 0.0 | 4.8 | 697.2 | 0.0 | 5.1 | 0.1 | 2.0 | 0.0 | 0.0 |
| Tangors | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 17.0 | 0.0 | 0.0 |
| Other | 0.1 | 1.0 | 0.9 | 125.8 | 0.3 | 57.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| Certified Organic | | | | | | | | | | |
| Orange | 1.2 | 18.5 | 0.6 | 85.3 | 1.0 | 208.7 | 0.2 | 6.1 | 0.5 | 3.0 |
| Lemon | 0.2 | 3.0 | 0.0 | 0.0 | 0.7 | 157.1 | 0.0 | 0.1 | 0.0 | 0.0 |
| Mandarins | 2.7 | 42.5 | 0.0 | 1.0 | 0.1 | 23.2 | 0.0 | 0.1 | 0.8 | 5.0 |
| Grapefruit | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 44.6 | 0.0 | 0.0 | 12.8 | 77.0 |
| Tangelos | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.3 | 0.0 | 0.0 | 0.5 | 3.0 |
| Tangors | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 2.0 |
| Other | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.4 | 0.0 | 0.1 | 0.0 | 0.0 |
| Total | | 169 | | 22938.31 | | 8799.53 | | 1932.6 | | 293 |

In addition to citrus, respondents grow an average of 25.7 acres of other fruits (Table 2). On average, they also grow 22.3 and 17.3 acres of livestock and vegetables, respectively. The "other" category includes wheat, oats, and herbs.

**Table 2. Summary Statistics of Respondents' Reported Non-Citrus Acreage (422 Respondents Reported Acreage)**

| Variety | Mean Reported Acres | Standard Deviation | Min | Max | Total Reported Acres |
|---|---|---|---|---|---|
| Conventional | | | | | |
| Fruit | 25.7 | 235.3 | 0.0 | 4,000.0 | 10,829.2 |
| Livestock* | 22.3 | 268.9 | 0.0 | 5,000.0 | 9,426.0 |
| Vegetables | 17.3 | 255.9 | 0.0 | 5,000.0 | 7,271.2 |
| Nuts | 11.4 | 178.5 | 0.0 | 3,500.0 | 4,818.6 |
| Other | 9.0 | 93.4 | 0.0 | 1,447.0 | 3,785.0 |
| Certified Organic | | | | | |
| Fruit | 0.8 | 8.5 | 0.0 | 170.0 | 317.9 |
| Vegetables | 0.0 | 0.5 | 0.0 | 10.0 | 18.8 |
| Livestock* | 0.1 | 2.9 | 0.0 | 60.0 | 63.0 |
| Nuts | 0.0 | 0.0 | 0.0 | 0.3 | 0.3 |
| Other | 0.1 | 1.0 | 0.0 | 20.0 | 25.0 |
| Total | | | | | 36,555.0 |

* Acres devoted to livestock production.

After asking about acreage of citrus and non-citrus, the survey asks respondents where they sell their output. About 65.1% of respondents' output is sold to packers or shippers, on average (Table 3). The "other" category is the second most common output outlet. This category predominantly includes sales to restaurants and schools and sales-on-site.

**Table 3. Average Percentage of Respondents' Output Sold to Outlet (415 Respondents Reported Production Outlets)**

| Outlet | Mean Reported % | Standard Deviation | Min % | Max % |
|---|---|---|---|---|
| Packer or Shipper | 65.1 | 46.6 | 0.0 | 100.0 |
| Other | 8.7 | 26.9 | 0.0 | 100.0 |
| Farmers' Market/Fruit Stand | 8.1 | 25.8 | 0.0 | 100.0 |
| Processor | 6.3 | 23.3 | 0.0 | 100.0 |
| Grocery Wholesaler/Distributor | 3.5 | 16.9 | 0.0 | 100.0 |
| Broker | 3.0 | 16.0 | 0.0 | 100.0 |
| Grocery Retailer | 1.6 | 10.7 | 0.0 | 100.0 |
| Community Supported Agriculture Boxes | 0.7 | 6.9 | 0.0 | 100.0 |
| Grocery Cooperative | 0.5 | 6.3 | 0.0 | 100.0 |

The vast majority of respondents produce on land they own. Eleven farm managers responded, compiling records from farms they manage, and 20 respondents reported producing citrus on rented land (Table 4).

**Table 4. Respondents' Reported Acres Owned, Managed, or Rented (409 Respondents)**

| Property Right | Mean Reported Acres | Standard Deviation | Minimum Acres | Maximum Acres | Number of Respondents |
|---|---|---|---|---|---|
| Owned | 52.7 | 171.3 | 0.0 | 2,526.0 | 396 |
| Managed | 21.3 | 295.0 | 0.0 | 5,650.0 | 11 |
| Rented | 7.9 | 90.5 | 0.0 | 1,639.0 | 20 |

After gathering basic information about citrus growers' production operations, the survey asks about pest presence and pesticide applications. Citrus thrips is the most commonly reported pest, with 54.8% of respondents reporting it present (Table 5). Red scale is the second most commonly reported pest with 47.7% of respondents reporting its presence. Overall, a higher proportion of respondents from the San Joaquin Valley Region report the presence of the four pests and report applying a pesticide to treat the pest(s).

**Table 5. Percentage of Respondents without Pest Present, with Pest but without Insecticide Application, and with Pest Present with Pesticide Application, Overall and by Region**

| Pest | Pest Not Present | Pest Present, No Insecticide | Pest Present, Insecticide Applied | Number of Respondents |
|---|---|---|---|---|
| Thrips: All Regions | 45.2% | 24.2% | 30.6% | 389 |
| Northern Region | 26.7% | 40.0% | 33.3% | 15 |
| San Joaquin Valley Region | 14.3% | 16.5% | 69.2% | 133 |
| Coastal- Intermediate Region | 67.3% | 27.2% | 5.4% | 202 |
| Interior Region | 50.0% | 21.9% | 28.1% | 32 |
| Desert Region | 0.0% | 80.0% | 20.0% | 5 |
| Red Scale: All Regions | 52.3% | 28.9% | 18.8% | 394 |
| Northern Region | 40.0% | 33.3% | 26.7% | 15 |
| San Joaquin Valley Region | 40.4% | 26.5% | 33.1% | 136 |
| Coastal- Intermediate Region | 60.8% | 28.9% | 10.3% | 204 |
| Interior Region | 50.0% | 40.6% | 9.4% | 32 |
| Desert Region | 80.0% | 0.0% | 20.0% | 5 |
| Red Mite: All Regions | 69.4% | 23.5% | 7.1% | 393 |
| Northern Region | 85.7% | 14.3% | 0.0% | 14 |
| San Joaquin Valley Region | 62.5% | 22.8% | 14.7% | 136 |
| Coastal- Intermediate Region | 71.0% | 25.6% | 3.4% | 207 |
| Interior Region | 78.1% | 18.8% | 3.1% | 32 |
| Desert Region | 100.0% | 0.0% | 0.0% | 4 |
| Cottony Cushion Scale: All Regions | 70.1% | 27.1% | 2.8% | 391 |
| Northern Region | 68.8% | 31.3% | 0.0% | 16 |
| SJV Region | 60.7% | 34.1% | 5.2% | 135 |
| Coastal- Intermediate Region | 77.3% | 20.7% | 2.0% | 203 |
| Interior Region | 64.5% | 35.5% | 0.0% | 31 |
| Desert Region | 75.0% | 25.0% | 0.0% | 4 |

Of the four pests, citrus thrips and red scale chemical control varies the most across respondents, with 27 and 21 different pesticides reported, respectively (Table 6).

**Table 6. Pesticides Applied and Number of Respondents Reporting Applications of Pesticide by Pest Controlled**

| Citrus Thrips | | Red Scale | | Citrus Red Mite | | Cottony Cushion Scale | |
|---|---|---|---|---|---|---|---|
| Pesticide | # Applying | Pesticide | # Applying | Pesticide | # Applying | Pesticide | # Applying |
| Success | 56 | Lorsban | 21 | Oil | 11 | Lorsban | 4 |
| Delegate | 19 | Esteem | 20 | Kanemite | 4 | Supracide | 2 |
| Carzol | 12 | Oil | 14 | Agri-Mek | 3 | Dimethoate | 1 |
| Baythroid | 11 | Admire | 9 | Danitol | 3 | Esteem | 1 |
| Agri-Mek | 9 | Movento | 5 | Abacus | 2 | Limonene | 1 |
| Dimethoate | 8 | Applaud | 4 | Nexter | 2 | Malathion | 1 |
| Oil | 7 | Alias | 3 | Onager | 2 | Oil | 1 |
| Veratran | 7 | Assail | 3 | Orocit | 2 | | |
| Renounce | 5 | Dimethoate | 2 | Abba | 1 | | |
| Epi-Mek | 3 | Orocit | 2 | Avemec | 1 | | |
| Abacus | 2 | Agri-Mek | 1 | Carzol | 1 | | |
| Lorsban | 2 | Citrus Knight | 1 | Envidor | 1 | | |
| Orocit | 2 | Couraze | 1 | Epi-Mek | 1 | | |
| Abba | 1 | Epi-Mek | 1 | Fujimite | 1 | | |
| Avemec | 1 | Limonene | 1 | Limonene | 1 | | |
| Cedar Guard | 1 | Montana | 1 | Mustang Max | 1 | | |
| Citrus Knight | 1 | Nuprid | 1 | Nufos | 1 | | |
| Danitol | 1 | Nupros | 1 | | | | |
| Ecotrol | 1 | Seize | 1 | | | | |
| Entrust | 1 | Sulfur | 1 | | | | |
| Evergreen | 1 | Supracide | 1 | | | | |
| Knack | 1 | | | | | | |
| Movento | 1 | | | | | | |
| Mustang Max | 1 | | | | | | |
| Nexter | 1 | | | | | | |
| Pygamic | 1 | | | | | | |
| Zoro | 1 | | | | | | |

In addition to chemical controls, the survey asks respondents about biological control methods. Forty-seven respondents report purchasing and releasing *Aphytis melinus* for red scale control, with releases most commonly occurring in the San Joaquin Valley and the Coastal-Intermediate Regions. Fifteen respondents report purchasing and releasing *Cryptolaeumus montrouzieri*, for mealybug control, and all but one of these respondents produce in the Coastal-Intermediate Region (Table 7). Fifteen growers report releasing other organisms, including decollate snails, ladybugs, and snakes for biological control.

**Table 7. Summary Statistics of Respondents' Natural Enemy Releases, Overall and by Region**

| | | If Releasing | | | |
|---|---|---|---|---|---|
| | Number of Respondents Releasing | Average Number of Releases | Standard Deviation | Min | Max |
| *Aphytis Melinus*: All Regions | 47 | 4.1 | 3.8 | 1 | 18 |
| Northern Region | 1 | 3.0 | | 3 | 3 |
| San Joaquin Valley Region | 17 | 6.0 | 5.4 | 1 | 18 |
| Coastal- Intermediate Region | 24 | 3.2 | 2.0 | 1 | 6 |
| Interior Region | 5 | 2.2 | 1.3 | 1 | 4 |
| Desert Region | 0 | | | | |
| *Cryptolaemus Montrouzieri:* All Regions | 15 | 1.7 | 1.0 | 1 | 4 |
| Northern Region | 0 | | | | |
| San Joaquin Valley Region | 0 | | | | |
| Coastal- Intermediate Region | 14 | 1.7 | 1.0 | 1 | 4 |
| Interior Region | 1 | 2.0 | | 2 | 2 |
| Desert Region | 0 | | | | |
| Other: All Regions | 15 | 1.7 | 1.1 | 1 | 4 |
| Northern Region | 0 | | | | |
| San Joaquin Valley Region | 3 | 1.0 | 0.0 | 1 | 1 |
| Coastal- Intermediate Region | 10 | 1.9 | 1.3 | 1 | 4 |
| Interior Region | 2 | 1.5 | 0.7 | 1 | 2 |
| Desert Region | 0 | | | | |

In addition to asking about released organisms, the survey asks about naturally occurring (not purchased or collected from elsewhere and released) natural enemies of the pests of interest. The most common naturally occurring natural enemy is the vedalia beetle (Table 8). Interestingly, respondents report that the cottony cushion scale is the least common pest. The cottony cushion scale is the vedalia beetle's only food source. Likely, more respondents have cottony cushion scale present but the beetle keeps it below economic thresholds.

**Table 8. Percentage of Respondents Reporting that the Natural Enemy is Naturally Occurring, Not Naturally Occurring, or They Do Not Know, Overall and by Region**

| Natural Enemy | Naturally Occurring | Not Naturally Occurring | Unknown | Number of Respondents |
|---|---|---|---|---|
| Vedalia Beetle: All Regions | 26.8% | 24.6% | 48.6% | 284 |
| Northern Region | 50.0% | 12.5% | 37.5% | 8 |
| San Joaquin Valley Region | 5.6% | 25.4% | 69.0% | 71 |
| Coastal- Intermediate Region | 16.5% | 30.9% | 52.5% | 139 |
| Interior Region | 26.1% | 30.4% | 43.5% | 23 |
| Desert Region | 0.0% | 50.0% | 50.0% | 2 |
| *Aphytis Melinus*: All Regions | 22.3% | 26.5% | 51.3% | 310 |
| Northern Region | 33.3% | 22.2% | 44.4% | 9 |
| San Joaquin Valley Region | 26.5% | 23.9% | 49.6% | 113 |
| Coastal- Intermediate Region | 16.9% | 30.0% | 53.1% | 160 |
| Interior Region | 36.0% | 20.0% | 44.0% | 25 |
| Desert Region | 0.0% | 0.0% | 100.0% | 1 |
| *Euseius Tularensis*: All Regions | 21.9% | 21.0% | 57.1% | 329 |
| Northern Region | 30.0% | 20.0% | 50.0% | 10 |
| San Joaquin Valley Region | 29.0% | 16.9% | 54.0% | 124 |
| Coastal- Intermediate Region | 16.6% | 25.2% | 58.3% | 163 |
| Interior Region | 22.2% | 18.5% | 59.3% | 27 |
| Desert Region | 0.0% | 0.0% | 100.0% | 3 |

The survey asks respondents about their reliance on the three natural enemies for pest control. Less than 18% of respondents reported relying on the vedalia beetle for control of the cottony cushion scale; the San Joaquin Valley has the highest percentage of respondents relying on the beetle to some extent (Table 9). A little more than 26% of respondents reported relying on *Aphytis melinus* for control of red scale, with 11.4% relying entirely on *A. melinus* for control. The Interior and Northern Regions have the highest percentages of respondents relying entirely on *A. melinus* for red scale control. Just under 19% of respondents make use of *Euseius tularensis* for red mite or thrips control. The Northern and San Joaquin Valley Regions have the highest percentages of respondents relying on *E. tularensis* to some extent.

**Table 9. Extent of Reliance on Natural Enemy for Pest Control, Overall and by Region**

| | Pest Not Present | Pest Present, Did Not Rely on Natural Enemy | Somewhat Relied on Natural Enemy | Mostly Relied on Natural Enemy | Entirely Relied on Natural Enemy | Number of Respondents |
|---|---|---|---|---|---|---|
| Vedalia Beetle/Cottony Cushion Scale | | | | | | |
| All Regions | 70.7% | 11.6% | 5.0% | 5.8% | 6.9% | 379 |
| Northern | 71.4% | 7.1% | 7.1% | 7.1% | 7.1% | 14 |
| SJV | 61.8% | 10.3% | 8.8% | 9.6% | 9.6% | 136 |
| Coastal | 76.9% | 12.8% | 3.1% | 2.6% | 4.6% | 195 |
| Interior | 72.4% | 6.9% | 0.0% | 10.3% | 10.3% | 29 |
| Desert | 75.0% | 25.0% | 0.0% | 0.0% | 0.0% | 4 |
| *Aphytis Melinus*/California Red Scale | | | | | | |
| All Regions | 51.6% | 22.2% | 9.3% | 5.6% | 11.4% | 378 |
| Northern | 61.5% | 7.7% | 7.7% | 7.7% | 15.4% | 13 |
| SJV | 40.2% | 35.6% | 9.8% | 7.6% | 6.8% | 132 |
| Coastal | 57.9% | 16.2% | 8.6% | 5.1% | 12.2% | 197 |
| Interior | 50.0% | 13.3% | 10.0% | 0.0% | 26.7% | 30 |
| Desert | 100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 4 |
| *Euseius Tularensis*/Citrus Thrips and/or Red Mite | | | | | | |
| All Regions | 45.0% | 36.0% | 7.3% | 5.4% | 6.2% | 369 |
| Northern | 42.9% | 28.6% | 14.3% | 7.1% | 7.1% | 14 |
| SJV | 18.5% | 55.4% | 12.3% | 7.7% | 6.2% | 130 |
| Coastal | 63.5% | 22.4% | 4.2% | 3.1% | 6.8% | 192 |
| Interior | 50.0% | 32.1% | 3.6% | 10.7% | 3.6% | 28 |
| Desert | 0.0% | 100.0% | 0.0% | 0.0% | 0.0% | 4 |

Cultural controls are the last methods of pest control that the survey addresses. The majority of respondents make use of weed reduction, water management, sucker removal, and skirt pruning to aid in pest control (Table 10).

**Table 10. Percent of Respondents Using the Given Cultural Control Method and the Reported Targeted Pests (399 Respondents)**

| Cultural Control | Percent of Respondents Using Method | Reported Targeted Pests |
|---|---|---|
| Weed Reduction | 70.4% | ants, gophers, katydids, leafhoppers, mealybug, rabbits, red scales, rots, sand fleas, snails, squirrels, thrips, voles, |
| Water Management | 54.6% | ants, leafhoppers, mites, phytophthera, red scale, root rot, snails |
| Sucker Removal | 52.1% | ants, leafminer, mealybugs, red scale, snails, thrips |
| Skirt Pruning | 51.6% | ants, katydids, mites, peelminer, red scale, rots, slugs, snails, |
| Clean Orchard Floor | 48.6% | ants, brown rot, gophers, katydids, mealybugs, medfly, red scale, sand fleas snails, thrips, weeds, worms |
| Removal of All Fruits | 20.8% | ants, citricola scale, fruit flies, rats, red scale, rots, snails |
| Mulches | 20.3% | mites, root rot, root weevil, weeds |
| Dust Reduction Measures | 19.8% | mites, scales |
| Cover Crops to Provide Habitat for Natural Enemies | 11.3% | aphids, birds, mites, root rot, snails, thrips |
| Early Harvest | 7.0% | botrytis, raccoons, red scale, snails, squirrels |
| Other | 4.8% | ants, gophers, snails |
| Hedgerows to Provide Habitat for Natural Enemies | 4.3% | no specific pests reported |

After asking about pest control practices, the survey asked about growers' most important sources of pest control information. Crop consultants and pest control advisors are the most important sources of pest control information for 56% of respondents (Table 11). Extension advisors and other growers are second and third, respectively.

**Table 11. Percent of Respondents Reporting a Given Source as Their Primary Information Source (343 Respondents)**

| Information Source | Percent |
|---|---|
| Crop Consultant or Pest Control Advisor | 56.0 |
| Extension Advisors | 13.7 |
| Other Growers | 8.2 |
| Farm Suppliers or Chemical Dealers | 7.3 |
| Other Source | 6.7 |
| Extension Publications | 4.4 |
| Organic Certifying Agent | 3.8 |
| Newsletters, Trade Magazines | 1.2 |

For conventional growers, the survey concludes with a section asking about grower characteristics (Table 12). The majority of respondents are white males. The average education level is a college degree. Average age and average farming experience are 64.2 years and 25.7 years, respectively. Revenues from farming make up less than 33% of household income for the average grower.

**Table 12. Respondent Characteristics**

| | Average | Standard Deviation | Minimum | Maximum | Number of Respondents |
|---|---|---|---|---|---|
| Education | College Degree | | Some High School | Graduate or Professional Degree | 393 |
| Age | 64.2 | 12.8 | 24.0 | 94.0 | 384 |
| Years Managing Current Farm | 22.8 | 15.0 | 1.0 | 85.0 | 394 |
| Years Managing Any Farm | 25.7 | 15.7 | 1.0 | 85.0 | 394 |
| % Income from Farming | 32.8 | 36.9 | -15.0 | 100.0 | 373 |
| % Income from Citrus | 25.9 | 33.0 | -4.0 | 100.0 | 375 |
| | Percent | | | | |
| Female | 18.0 | | | | 389 |
| Ethnicity | | | | | |
| White | 86.4 | | | | 389 |
| Hispanic, Spanish, Latino | 6.4 | | | | 389 |
| Asian or Asian American | 3.6 | | | | 389 |
| American Indian or Native American | 0.5 | | | | 389 |
| Black | 0.3 | | | | 389 |
| Other[2] | 3.3 | | | | 389 |

After answering questions on grower characteristics, the survey asks organic growers to answer questions pertaining to organic production. The first question asks organic growers when they began organic certification for citrus and non-citrus, if applicable. Most respondents first became certified in 2000 or later, but respondents report obtaining organic certification as early as 1985 for citrus and 1982 for non-citrus (Tables 13a and b).

[2] The majority of respondents in the "other" category entered "human" or "American" as their race. Essentially, these respondents declined to report their race.

**Table 13a. Number of Growers Reporting That Certification of Citrus Began in a Given Year**

| Year | Number Beginning Certification | Year | Number Beginning Certification |
|---|---|---|---|
| 1985 | 1 | 2000 | 3 |
| 1987 | 1 | 2001 | 4 |
| 1990 | 1 | 2002 | 6 |
| 1993 | 1 | 2003 | 3 |
| 1994 | 1 | 2004 | 5 |
| 1995 | 2 | 2005 | 4 |
| 1996 | 1 | 2006 | 4 |
| 1997 | 2 | 2007 | 5 |
| 1998 | 1 | 2008 | 6 |
| 1999 | 1 | 2009 | 4 |
| Total | | | 56 |

*4 growers reported being in transition to certified organic citrus production, 2 stated that production was organic and organic premiums were obtained but were not certified, 1 grower produced organic avocados but no organic citrus, 1 chose not to report the year certified.

**Table 13b. Number of Growers Reporting That Certification of Non-Citrus Began in a Given Year**

| Year | Number Beginning Certification | Crop if reported | Year | Number Beginning Certification | Crop if reported |
|---|---|---|---|---|---|
| 1982 | 1 | prunes, mixed vegetables | 2001 | 2 | avocados |
| 1990 | 1 | | 2002 | 2 | avocados |
| 1991 | 1 | apples, avocados, persimmons | 2003 | 1 | |
| 1993 | 1 | vegetables | 2004 | 3 | kiwi, lavender, rosemary, vegetables |
| 1995 | 1 | | 2005 | 1 | avocados |
| 1997 | 1 | avocados | 2006 | 1 | avocados |
| 1998 | 1 | avocados | 2007 | 3 | avocados, squash, tomatoes |
| 1999 | 1 | tomatoes | 2008 | 3 | avocados, pomegranates |
| 2000 | 3 | avocados | 2009 | 1 | avocados |
| Total | | | | | 28 |

Organic certification requires that the certified land be managed with organic methods for three years prior to certification. The survey asks growers how they began certification and satisfied this management requirement. The majority of organic respondents transitioned land from conventional production to organic production, waiting for three years to obtain certification (Table 14). Seven respondents purchased or rented new land to begin producing organically. Others purchased land that was previously managed organically.

**Table 14. Reported Transitions to Organic Production**

| How Respondent Began Organic Production | Number of Respondents |
|---|---|
| Transitioned Land from Conventional to Organic | 46 |
| Purchased or Rented New Land to Begin Production Organically | 7 |
| Other | |
| Purchased Land that was Previously Certified Organic | 3 |
| Purchased Land That was Managed Organically, but Not Certified | 5 |

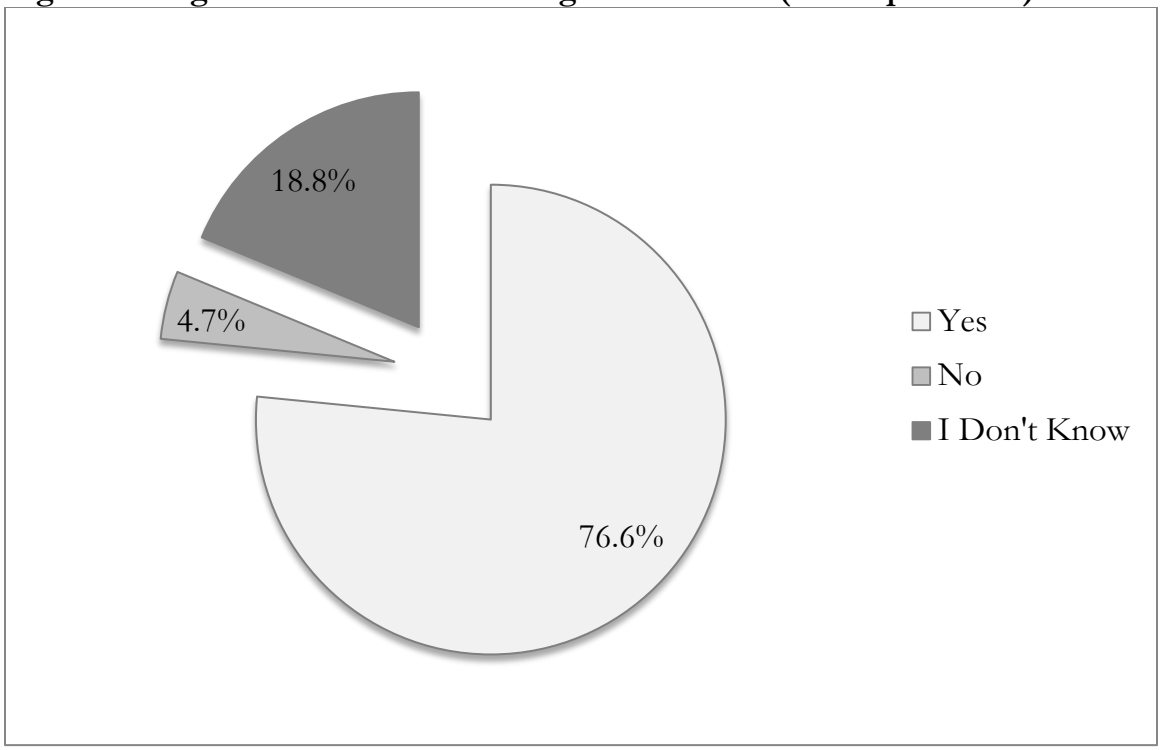
The survey asks growers what percent of their output they sold or expected to sell at an organic price premium. On average, organic respondents sell about 76% of their output at a price premium (Table 15). Seven respondents report that none of their organic citrus output was or would be sold at an organic price premium. For organic respondents, the sale of organic citrus and value-added products makes up almost 56% of their total farm sales, on average.

**Table 15. Reported Percentage of Citrus Output Sold at an Organic Price Premium and Percent of Total Farm Sales from the Sale of Certified Organic Citrus**

| | Average | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Percent of Organic Citrus Sold at Organic Price Premium | 75.6% | 39.1 | 0% | 100% |
| Percent of Total Farm Sales from Sale of Certified Organic Citrus (including value-added products) | 55.8% | 47.2 | 0% | 100% |

In order to continue marketing produce as certified organic, growers must renew their certifications and pay a renewal fee that varies based on their certifier and farm size. The survey asks organic growers if they intend to continue organic certification for the next several years. Almost 77% reported that they planned to renew for the next several years, while almost 5% did not plan to renew and almost 19% were not sure if they would renew (Figure 1)

**Figure 1. Organic Growers Continuing Certification (64 Respondents)**




Those respondents who reported that they will or may discontinue organic certification were asked to report a reason why they will not continue certification. Fourteen growers responded to this question, with five respondents reporting two reasons. The two most common reasons for discontinuing certification are that certification is too expensive and organic price premiums are insufficient (Table 16). The "other" category includes production problems, difficulty selling output from a small operation, too much paperwork, and too many threats from an unidentified source or sources.

**Table 16. Reason(s) Why Organic Respondent Will Discontinue Certification**

| Reason | Number Reporting |
|---|---|
| Certification is too expensive. | 6 |
| I do not receive sufficient organic price premiums. | 6 |
| Other | 4 |
| My customers will continue to buy my products even if they are not certified organic. | 3 |

For organic growers, the survey concludes by asking respondents to rate various possible reasons for choosing to produce organically on a scale of one to five in terms of the reasons' importance in their own decisions to grow organically. Reasons ranked as a "5" are very important, while those ranked as "1" are not important. Economic incentives rank highest; demand for consumer products and organic price premiums are the most important factors for organic respondents (Table 17). Environmental sustainability and health reasons are also

important factors. Farm diversification and reduced input costs are the least important. Three respondents wrote on their surveys that input costs are higher for organic production.

**Table 17. Importance of Reasons to Produce Organically**

| | Average | Standard Deviation | Min | Max | Number Responding |
|---|---|---|---|---|---|
| Consumer demand for organic products | 4.3 | 1.1 | 1 | 5 | 59 |
| Price premiums for certified organic products | 4.3 | 1.1 | 1 | 5 | 62 |
| Environmental sustainability | 4.2 | 1.1 | 1 | 5 | 62 |
| Increased profitability of growing organically (relative to conventional production) | 4.2 | 1.0 | 2 | 5 | 58 |
| Personal, family, or farm worker health | 4.1 | 1.3 | 1 | 5 | 60 |
| Health of consumers | 4.0 | 1.2 | 1 | 5 | 62 |
| Intellectually appealing | 3.5 | 1.4 | 1 | 5 | 61 |
| Philosophical or spiritual reasons | 3.3 | 1.5 | 1 | 5 | 60 |
| Farm diversification | 2.6 | 1.6 | 1 | 5 | 55 |
| Reduced input costs | 2.6 | 1.6 | 1 | 5 | 55 |

## Statistical Analysis

The statistical analysis tests whether or not the use of certain pesticides in nearby fields affects respondents' beneficial insect populations and pest control decisions. Because *Aphytis melinus* is the most commonly used beneficial insect among respondents and because it is commercially available, the statistical analysis focuses on the effects of nearby pesticide use on the use of this beneficial insect. The analysis considers the effects of pesticide use within an 18 mile by 18 mile block surrounding each respondent and considers the use of pesticides on both citrus and non-citrus fields. We obtained records of all pesticide applications within these blocks from the California Department of Pesticide Regulation's Pesticide Use Reporting database. We will refer to pesticide use within this geographical block as "surrounding" use.

We first estimate the effects of surrounding pesticide use on whether or not respondents reported that *A. melinus* was present during the 2009 growing season. The use of carbaryl, chlorpyrifos, and methidathion on surrounding non-citrus fields appears to decrease the probability that respondents have the beneficial insect present. However, the magnitude of the effect is small. This is most likely because pesticide use lowers rather than eliminates populations of the insect.

Next, we examine how the surrounding use of pesticides affects the probability that the respondent applied a chemical control for red scale. We hypothesize that the use of pesticides that are toxic to *A. melinus* in a grower's region will increase the probability that

the grower relies on chemical control of the scale because the beneficial insect populations will be reduced. Indeed, we find that surrounding use of carbaryl, chlorpyrifos, and methidathion on non-citrus fields increases the probability that respondents relied on chemical control of red scale. A respondent surrounded by non-citrus use of these pesticides that falls at the 75$^{th}$ percentile (relatively high pesticide usage) is 28% more like to rely on chemical control than a respondent surrounded by a median level of the use of these pesticides. This suggests that the use of these three pesticides on nearby non-citrus fields lowers populations of *A. melinus* on respondents' fields, necessitating chemical control of red scale.

Finally, we consider how surrounding pesticide use affects respondents' choices of which red scale control to use. We rank respondents' pest control methods in order of compatibility with an IPM program. We do not find any effect of surrounding pesticide use on citrus or non-citrus fields on the level of IPM compatibility chosen by respondents. This suggests that those growers who face lowered *A. melinus* population levels still choose IPM compatible pesticides.

Our results suggest that *A. melinus* could provide more effective red scale control if the use of carbaryl, chlorpyrifos, and methidathion on non-citrus fields in citrus growing regions were reduced.

Our statistical analysis also looks at other factors affecting respondents' pest control decisions. Not surprisingly, our results show that growers who sell a higher share of their output to processors are less likely to apply a pesticide to control for red scale. We also find that Hispanic growers and growers of "other" ethnicity are about 37% and 32% less likely to apply a pesticide for red scale control, respectively, than white growers.

Our analysis shows that growers with more citrus acres are more likely to choose a higher level of IPM compatibility than growers with fewer citrus acres. However, controlling for citrus acres, growers with more total acres (citrus and non-citrus acres) choose lower levels of IPM compatibility. Growers with higher levels of education are likely to choose higher levels of IPM compatibility than growers with lower levels of education.

Pest control information sources are also significant determinants of IPM compatibility. Growers relying on chemical suppliers for their pest control information are more likely to apply chlorpyrifos to control red scale than growers relying on pest control advisors for their pest control information. Growers who rely on other growers and "other" information sources are more likely to make use of *A. melinus* than growers who rely on pest control advisors. "Other" information sources included internet research, entomologists, and personal experience. Finally, Asian growers are more likely to make use of chlorpyrifos and spirotetramat to control red scale than white growers.

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