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The Effect of Landscape-level Pesticide Applications on California Citrus Growers' Decisions for California Red Scale Management

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The mobility of many pests potentially allows nearby growers to affect each other through their pest management decisions. Using data from a 2010 survey of California citrus growers, we explore growers' use of a specific beneficial insect, *Aphytis melinus*, which parasitizes California red scale, a major citrus pest. The extent of growers' reliance on *A. melinus* and whether or not they choose to make augmentative releases varies with their production region and other characteristics. We also analyze how landscape-level pesticide use affects growers' decisions regarding whether or not to apply an insecticide to control California red scale. In some cases, pesticides applied on non-citrus increase the probability of an insecticide treatment for California red scale control on citrus fields.

Also in this issue

Aphytis melinus, a parasitic wasp, lays its eggs under the California red scale, a primary citrus pest. When the wasp's eggs hatch, the larvae consume the scale. The wasp is produced by commercial insectaries and can be purchased and released by growers to augment natural populations and improve the control of California red scale. However, applications of some pesticides will reduce *A. melinus* populations.

Chemical controls may be used to manage California red scale instead of, or in conjunction with, biological control provided by *A. melinus*. We examine whether or not pesticide use in the surrounding area affects a California citrus grower's decision to apply insecticide to manage California red scale. If others' pesticide use increases the likelihood that a grower applies an insecticide, then there is a negative externality of pesticide use.

We separate these pesticides into two types: pesticides used to control California red scale and other citrus pests, including carbaryl (Sevin™), chlorpyrifos (Lorsban™), and methidathion (Supracide™); and, pesticides not used to control California red scale but are used to manage other citrus pests, including acetamiprid (Assail™), cyfluthrin (Baythroid™), and fenpropathrin (Danitol™).

The potential cross-effects of growers' pest management decisions are not limited to citrus growers. These pesticides are also used on non-citrus crops, and *A. melinus* provides control of certain pests of non-citrus crops as well.

We surveyed California citrus growers in spring 2010 regarding the presence and management decisions for four major citrus pests in the 2009–10 season, as well as other information regarding the operation and grower. Using information from 18 county agricultural commissioners' offices, surveys were mailed to 3,480 growers. Of these individuals, 429 responded, resulting in a 12.3% response rate. Some respondents did not answer all questions, so we report the number of respondents in each table below.

The presence of California red scale reported by respondents varied by region, as shown in Table 1, as did growers' decisions on whether or not an insecticide treatment was required for managing it. Growers in the San Joaquin Valley, who face the environment most favorable for pest development, were most likely to apply an insecticide. Growers in the coastal-intermediate and interior regions were least likely to do so.

Currently efforts are underway to eradicate California red scale in the desert region. The eradication program mandates growers' responses to an infestation, so we exclude the desert region from the remainder of the analysis. California red scale was least likely to be reported present in

Table 1. California Red Scale Presence and Insecticide Use, Overall and by Region (N=394)

Region	% Pest Not Present	% Pest Present, No Insecticide	% Pest Present, Insecticide Applied
All	52.3	28.9	18.8
Northern Region	40.0	33.3	26.7
San Joaquin Valley Region	40.4	26.5	33.1
Coastal-Intermediate Region	60.8	28.9	10.3
Interior Region	50.0	40.6	9.4
Desert Region	80.0	0.0	20.0

that region, and, when reported present, required an insecticide treatment.

Use of Biological Control

An integrated pest management program may include biological, cultural, and chemical controls. The survey asked growers three questions regarding their use of *A. melinus* for California red scale control. The first question regarded whether or not there was a natural population of *A. melinus* in the grower's groves (Table 2). The second queried the extent to which the grower relied on *A. melinus* for red scale control (Table 3). The third regarded whether or not the grower increased a natural population with augmentative releases.

Examining Table 2, roughly half of growers did not know whether or not a natural population of *A. melinus* was present. There are a number of possible reasons that may contribute to this high share, including, but not limited to, that growers did not scout for *A. melinus*, growers employed pest control advisors who scouted but did not tell the grower, or growers used augmentative releases and thus did not know whether there was a natural population or whether the existing population should be considered natural.

Among growers indicating knowledge of whether or not a natural population existed, a natural population was most likely to be reported present in the interior and northern regions, and least likely to be reported present in the cooler coastal-intermediate region. A little more than 26% of respondents reported relying on *A. melinus* for control of red scale, with 11.4% relying entirely on *A. melinus* for control (Table 3). The interior and northern regions had the highest percentages of respondents relying entirely on *A. melinus* for red scale control.

Forty-seven respondents reported purchasing and releasing *A. melinus* for California red scale control. Releases were the most common in the San Joaquin Valley (17 respondents) and the coastal-intermediate region (24 respondents). Five respondents in the interior region made augmentative releases, and one did in the northern region.

Table 2. Percentage of Respondents Reporting that *A. melinus* is Naturally Occurring, Not Naturally Occurring, or They Do Not Know, Overall and by Region (N=310)

Region	% Naturally Occurring	% Not Naturally Occurring	% Unknown
All	22.3	26.5	51.3
Northern Region	33.3	22.2	44.4
San Joaquin Valley Region	26.5	23.9	49.6
Coastal-Intermediate Region	16.9	30.0	53.1
Interior Region	36.0	20.0	44.0

Respondent Characteristics

There are a number of farm and grower characteristics that can influence pest management decisions. In order to identify any effects of landscape-level pesticide use on an individual grower's pest management decisions, we must control for the effects of these other characteristics. Table 4 reports key characteristics for all respondents, those who mostly or entirely relied on *A. melinus* for control of California red scale, and those who released *A. melinus*.

Growers who relied on and/or released *A. melinus* had substantially more citrus acreage and total acreage on average than did all respondents. Interestingly, respondents who had organic acreage were less likely to rely on or release the wasp than were all respondents. Of all respondents, a higher percentage of male growers relied on or released *A. melinus*; the same was true for white growers.

Growers who sold to a packinghouse or shipper were a higher percentage of respondents who relied on or released *A. melinus*. However, growers who relied on other marketing outlets, such as farmers' markets and processors, were much less likely to utilize *A. melinus*. Growers who relied primarily on a pest control advisor were more likely than other respondents to rely on or release *A. melinus*.

Statistical Analysis

The statistical analysis tests whether or not the use of certain pesticides in nearby fields affects respondents' choice of pest management techniques, specifically their reliance on *A. melinus* for California red scale control. 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 using data from the California Department of Pesticide Regulation's Pesticide Use Reporting database.

For the statistical analysis, we include three categories of pesticides: 1. Toxic to *A. melinus* only; 2. California red scale control, toxic to *A. melinus*; and 3. California red scale control only. The third category is included because the growers' choice of treatment may be influenced by the treatment choices of nearby growers, or by common biological factors or other considerations that they face. The results of the analysis regarding the variables of interest are reported in Table 5. The statistical model also controlled for the grower and farm characteristics summarized in Table 4.

We hypothesize that the surrounding use of pesticides that are toxic to *A. melinus* increases the probability that the respondent relies on chemical control of the scale because the beneficial insect populations will be reduced. We use a probit model that estimates the factors underlying a grower's decision to apply an insecticide as part of his California red scale management program to examine this hypothesis.

The results of the probit estimation (Table 5) provide partial support for this hypothesis. Surrounding use of insecticides that are toxic to *A. melinus* and used by non-citrus growers for California red scale control increases the probability that a respondent applies a chemical to treat California red scale.

Specifically, the use of three broad-spectrum pesticides on surrounding non-citrus fields—carbaryl (a carbamate), chlorpyrifos (an organophosphate), and methidathion (an organophosphate)—increases the probability that respondents relied on chemical control of California red scale. Table 5 reports the marginal effects of surrounding use of each group of pesticides on the likelihood that a citrus grower applies an insecticide for California red scale management.

The statistically significant support for our hypothesis is reported in the fifth row of Table 5. A respondent

Table 3. Extent of Reliance on *A. melinus* for California Red Scale Control, Overall and by Region (N=378)

	% With Pest Not Present	% With Pest Present, Did Not Rely on Natural Enemy	% Who Somewhat Relied on Natural Enemy	% Who Mostly Relied on Natural Enemy	% Who Entirely Relied on Natural Enemy
All Regions	51.6	22.2	9.3	5.6	11.4
Northern	61.5	7.7	7.7	7.7	15.4
SJV	40.2	35.6	9.8	7.6	6.8
Coastal	57.9	16.2	8.6	5.1	12.2
Interior	50.0	13.3	10.0	0.0	26.7

Table 4. Characteristics of All Respondents and Respondents Who Relied on or Released *A. melinus**

	All (N=422)	Mostly or Entirely Relied on (N=93)	Released (N=47)
Farm Characteristics			
Percent Non-Orange Acreage	39.1	38.8	37.0
Average Total Citrus Acres	76.4	224.7	402.1
Average Total Acres	167.6	347.0	632.9
Average Expected Value per Acre	$6,242	$6,445	$6,841
% of Growers with Organic Acreage	14.5	10.8	6.4
Grower Characteristics			
Median Education Level	-----------------College Degree---------------		
Average Experience (years)	25.7	29.9	29.4
Percent Female	18.0	14.9	15.9
Percent Race			
Asian	3.6	1.1	0.0
Hispanic	6.4	3.4	2.3
Other	3.6	4.6	4.5
Percent of Output Sold Through Outlet			
Packinghouse/Shipper	65.0	78.7	88.3
Processor	6.2	2.4	3.0
Other	21.7	3.3	4.3
Primary Source of Pest Control Information			
Pest Control Advisor	55.3	70.1	82.2
Extension Agent	13.5	9.2	4.4
Other Growers	8.1	2.3	0.0
Farm/Chemical Suppliers	7.2	0.0	0.0
Extension Publications	4.3	3.4	2.2
Organic Certifying Agent	3.7	0.0	0.0
Trade Magazines	1.1	1.1	2.2
Other	10.3	13.8	8.9

** Includes 5 respondents from the desert region*

Table 5. Marginal Effects of Determinants of Insecticide Application to Manage California Red Scale	Marginal Effects	Robust Standard Error
Surrounding Pesticide Use on Citrus		
Toxic to *A. melinus* only	-0.0424	(0.0587)
California Red Scale Control, Toxic to *A. melinus*	0.2377	(0.1641)
California Red Scale Control Only	-0.3542	(0.2962)
Surrounding pesticide use on non-citrus		
Toxic to *A. melinus* Only	-0.1168*	(0.0537)
California Red Scale Control, Toxic to *A. melinus*	0.2864*	(0.0993)
California Red Scale Control Only	0.0157	(0.1094)
N	145	
Pseudo-R2	0.323	
Likelihood-Ratio Test	12.84*	

** indicates significance at the 5% level.*

surrounded by non-citrus use of these pesticides that falls at the 75th percentile (relatively high pesticide usage) is 28% more likely 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 pesticides on nearby non-citrus fields lowers populations of *A. melinus* on respondents' fields, necessitating chemical control of California red scale.

On the other hand, contrary to expectations, the surrounding use of three pesticides toxic to *A. melinus* and not used by citrus growers to treat California red scale—acetamiprid, cyfluthrin, and fenpropathrin—reduces the likelihood that a respondent will apply an insecticide to treat California red scale.

Acetamiprid is used to control citricola scale as well as other non-citrus pests. While it is not used for California red scale control due to lower relative efficacy, it does suppress populations. Surrounding use of this pesticide may actually generate a positive externality by lowering the area's California red scale populations. In addition, acetamiprid is a neonicotinoid, and cyfluthrin and fenpropathrin are pyrethroids. While toxic to *A. melinus*, these pesticide classes are considered to have fewer negative environmental effects than organophosphates and carbamates.

The use of these pesticides may indicate that overall, growers use fewer broad spectrum pesticides in their integrated pest management programs, and that the cumulative effect of these management decisions enhances regional *A. melinus* populations. A third possibility is that the timing of applications of these pesticides relative to *A. melinus* population development mitigates their toxicity. We do not have the data required to examine these potential explanations or others.

Policy Implications

Regulation of pesticides is commonly justified based on negative externalities. These negative externalities are effects on environmental quality, ecosystems, or human health that are not borne, or primarily borne, by the grower making the pesticide application. The statistical analysis suggests that in some instances, another type of externality may exist: the application of pesticides or certain classes of pesticides may affect other growers' need to use chemical pesticides for the management of specific pests.

The analysis focused on surrounding use. This suggests that any regulatory consideration of potential cross-grower effects should take into account the possibility of local differences rather than beginning at the state or national level.

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For additional information, the authors recommend:

Grogan, Kelly A. and Rachael E. Goodhue. 2011. "California Citrus Pest Management Survey: A Summary of Responses." Department of Agricultural and Resource Economics, University of California, Davis. http://agecon.ucdavis.edu/people/faculty/rachael-goodhue/docs/CitrusSurveyResults2010.pdf.

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