DETERMINANTS OF ADOPTION OF ALTERNATIVES TO ORGANOPHOSPHATE USE IN CALIFORNIA ALMONDS

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Abstract. In order to explain trends in pesticide use, modeling efforts were undertaken related to dormant season organophosphate use in California almonds. Over time, growers are less likely to choose to use environmentally unfriendly pesticides, especially when effective alternatives are available. Growers are more likely to use harmful pesticides in years when they expect yields to be low and more likely to use them when price expectations are high. Educational and demonstration programs are effective in reducing the use of targeted pesticides. Growers are more likely to reduce the use of pesticides by avoiding use altogether than using pesticides on only part of their acreage.

Key words. organophosphates, pesticide reduction, pest management

Introduction

The California Department of Pesticide Regulation (DPR) began full use reporting of all agricultural pesticide applications in 1990 (DPR 2000). The program requires monthly reporting of all agricultural pesticide use to the county agricultural commissioners who transfer the information to DPR. The reports include the date, and time of the application, commodity treated, acres planted, acres treated, pesticide product and quantity applied, application method, and other grower identification information. Therefore, pesticide use report data (PUR) provide a wealth of information concerning the trends in pesticide use in California by commodity, region, and material. Observation of certain clear trends in pesticide use lead to questions as to the causes of these trends and the desire to predict future trends from past observations. While the statistical analysis of pesticide use trends is straightforward, explanations of the trends are not. The purpose of this study is to develop a methodology for analytically determining the factors influencing levels of pesticide use for classes of materials and to apply the methodology to a specific example, dormant organophosphate use in almonds.

General Methodology Development

The question of explaining patterns of pesticide use falls under the broader topic of determinants of technology adoption among farmers. The adoption literature includes work investigating the determinants of adoptions for individuals. The determinants of adoption are factors that influence the costs and benefits of adopting a given technology, in this case pesticide use. The characteristics of the technology itself influence the adoption choice. In addition to the characteristics of the technology itself, farmer and farm characteristics influence adoption decisions. These include management ability, farm size, access to capital, and attitude toward risk.

The adoption literature specific to the adoption of integrated pest management (IPM) practices is consistent with the general adoption literature. The characteristics of the IPM technique influence adoption. The IPM technique is less likely to be adopted if it leads to increases in non-target pests. The compatibility of the timing and resource needs of the IPM practice with other farm operations is also a factor influencing adoption.

Several generalizations can be made regarding the characteristics of the farmer and adoption. Numerous studies of IPM adoption conclude that IPM adopters are younger and better educated than non-adopters (Swinton and Day 2000). Early adopters are more inclined to take risks (Fernandez-Cornejo, et al. 1994). Awareness of long-term effects of pesticide use is also a factor in the adoption decision (Hill et al. 1990).

Economic factors impacting adoption decisions include the cost of the technology compared to other available methods. In other words, the relative costs of alternatives are considered. A pesticide may increase in cost, but to a lesser extent than a substitute, making it the preferred alternative even though its cost increased. The price of the commodity is equally important. Overall, growers spend more to protect higher value crops than lower value crops. On a year to year basis, relatively low prices often lead to cutting costs in anticipation of cash flow problems. High prices may encourage a farmer to try and maximize production. Finally, production under contract or destined for a particular processor or handler may be obligated to follow the cultural recommendations of a field representative in order to ensure a home for the product.

Arguably, the most important characteristic of the farm impacting adoption of pest control methods is pest pressure. Practices that impact secondary pests, overwintering and natural enemy populations can influence pest populations. Weather directly influences pest populations by providing favorable or unfavorable growth conditions. Weather also impacts the ability of growers to enter fields or orchards to spray. Therefore, variables such as accumulated degree days, precipitation, and timing of precipitation are all relevant for explaining the pesticide use decision. Other variables such as hours below or above a temperature threshold may also be important. Pest populations are usually highly correlated with pest populations from the previous year.

For example, an orchard with a history of mites is more likely to have a mite problem than an orchard with no history of mites.

The role of regulation is often mentioned in discussions of adoption of pest management practices. Regulation affects both the characteristics of the technology and the attitudes of growers. If a grower anticipates that a pesticide is going to be prohibited in the near future, worries about resistance developing are no longer a factor in the use decision. A grower may respond by wanting to identify viable alternatives before the pesticide is no longer available for use, or may decide to use the pesticide until it is no longer allowed. Some growers will take the impending regulation as a signal that the pesticide is causing some sort of environmental harm and will voluntarily suspend use.

Efforts by industry groups and the University of California to develop and promote pest control alternatives impact pesticide use decisions. Numerous studies show that educational efforts aimed at increasing knowledge of IPM techniques have succeeded in reducing pesticide use. Field days, seminars, publications, and web sites all provide information to growers and pest control advisors to encourage and enable adoption.

Implementation of General Methodology

The first step in the analysis is the formation of a set of hypotheses regarding the factors influencing the use of a specific category of pesticides for the target crop. Hypotheses can be solicited from experts including industry members, University researchers on campus and in Cooperative Extension offices, private pest control advisors, and other researchers on a crop by crop basis. Personal interviews with experts are invaluable for developing hypotheses related to all of the other areas mentioned including weather, pest control alternatives, farm characteristics, and farmer characteristics. Growers of a commodity within each production region are perhaps the most important and fundamental source of hypotheses. Ideas can be obtained through personal interviews or focus groups.

As background for the interviews and focus groups, the characteristics of individual pesticides commonly used for the crop in question, such as the relationship to control of secondary pests, efficacy, current and pending regulation, and resource requirements can be obtained from a variety of sources. First, the Pest Management Guidelines published by the University of California Integrated Pest Management Program provide a roadmap of alternative pest control practices by crop, pest, and material. The UCIPM website also includes results of trials related to specific crops, pests, and alternatives. Current legal restrictions on use of individual pesticides are clearly stated on the labels for that pesticide.

The next step in the analysis is the identification and collection of available data. Weather data is available through the California Irrigation Management Information System (CIMIS 2002). Weather data is collected throughout California from more than 100 weather stations. Historic information concerning pest populations and pest damage is more difficult to obtain. Rejects due to pest damage act as a proxy for pest populations for some crops where records of reject levels are maintained by processors and collected by marketing associations, boards, or coops.

As discussed earlier, the Pesticide Use Reports provide a wealth of information about the location, type, and amount of pesticides applied to crops in California. However, the database does not include information concerning farmer characteristics such as the size of the entire farming operation or financial structure. There are no inclusive studies of risk preferences, environmental concerns, or marketing strategies.

Efforts by industry, the University of California, and other groups to encourage the adoption of pest management strategies can often by modeled by a presence/absence variable when the beginning, duration, and location of the effort can be uniquely identified. These efforts can be determined through interviews of experts.

The final step in testing the hypotheses is the econometric analysis itself. Regression analysis estimates the effect of each explanatory factor on pesticide use independently, unlike correlation analysis, which does not account for the effects of other variables. Pesticide use can decrease in several ways. First, the number of growers using the pesticide can decrease, second, growers can continue to use a pesticide but on only a portion of their planted acreage, and third growers can continue to use the pesticide, but at lower rates than before. Therefore, trends in pesticide use should be measured in at least three ways. The first set of regressions examines whether or not individual producers chose to use the targeted set of pesticides in a given year. The second set looks at the percentage of planted acres treated with the pesticide(s) and third examines application rates per acre. These three together give a complete picture of the changes in pesticide use over time. The first says whether or not fewer growers are using a set of pesticides, the second says whether they are making the decision for all or part of their acreage, and the third says whether or not they are changing their application rates per acre.

Case Study: Dormant Season Organophosphate Use in California Almonds

In order to test the ability of the general methodology to explain trends in pesticide use, modeling efforts were undertaken related to dormant season organophosphate use in California almonds. Organophosphate (OP) dormant sprays control overwintering pests including Navel Orange Worm (NOW), San Jose scale, peach twig borer (PTB), and early season mites. The use of OPs in California began to come under scrutiny in the late 1980s when they began to show up in groundwater. Applications during the winter rainy season have been identified as the major source of OP runoff into surface water. Second, we know from the PURs that almonds accounted for 10 to 33 percent of dormant OP use in the years 1992 to 2000 (Zhang et al. 2004). In response, alternatives have been developed and encouraged through private and public research and education programs. Spring application of pyrethroids is one alternative to OPs for control of NOW and PTB but increase the risk of high mite populations later in the season and may require the application of miticides. BT is a second alternative control method for NOW and PTB, and is considered to have reduced risk of environmental harm. A complete discussion of reduced-risk alternatives to dormant organophosphate insecticides in almonds can be found in Elliott, et al. 2004.

The Department of Pesticide Regulation conducted an extensive statistical analysis of trends in dormant OP use in CA from 1992 to 2000 (Zhang et al. 2002). The DPR determined a downward trend in OP use in California over the past ten years measuring OP use as total pounds applied, percentage of total planted acreage treated, and numbers of growers who applied dormant OPs. The DPR study used several weather variables as proxies for pest pressure. These measures were correlated with each of the three measures of OP use implying an increase in OP use with pest pressure.

Dormant OP Use Hypotheses

Essentially there are three ways that use of a pesticide can be reduced; 1) the percentage of growers using the pesticide is lowered, 2) growers reduce the percentage of their acreage treated and 3) growers reduce the application rates per acre. Observation of the PUR data demonstrates a downward trend in all three of these measures (Figures 1-3). The challenge, then, is to explain these trends using regression analysis.

Hypotheses as to factors influencing the use of dormant OPs in almonds evolved from individual interviews with University of California Cooperative Extension Farm Advisors with almond responsibilities in Kern, Butte, Glenn, and Fresno counties, and interviews with DPR researchers. In addition, hypotheses emerged from a focus group of private pest control advisers and growers active in the northern Sacramento Valley.

The hypotheses formed fall into the categories of weather, economics, physical, education, and risk. Weather impacts OP spray decisions in several ways. In extremely wet years it is difficult or impossible to get equipment into the orchard and apply a dormant spray in the winter. This leads to cleanup sprays in the following spring for peach twig borer. Also, dormant sprays the year following the rain event should increase. Timing of BT and fungicides are critical to rain events. Specifically, BT should not be applied right before a rain and fungicides should be applied right before it rains.

Profitability was the number one reason given for skipping sprays. This includes prices received and reducing costs. All handlers give bonuses for low reject levels although bonus levels differ by handler. When handlers pay premiums for one percent or lower rejects then growers are more likely to put on a spray at hull split for control of Navel Orange Worm. These sprays may or may not be OPs. When the percent reject level for premiums is higher then growers are less likely to spray. Northern California tends to have higher quality and less volume than southern CA so reducing the number of rejects may be more important in the north than the south. Rejects are likely to go up in a light crop year so, in general, a smaller expected crop means more sprays. Growers are more willing to take risks in a low price year and high crop year.

The application cost is the same for OPs and pyrethroids but the cost of the material per acre is lower for pyrethroids. When growers do apply OPs they traditionally apply oil at the same time. Some growers who eliminate dormant OP use substitute a higher rate of dormant oil than would be applied in conjunction with an OP. Others think that if they are not going to use OP then why bother with oil. Growers also tend to apply a higher rate of oil for scale when they use pyrethroids than they would with OPs. The current reasoning is that if the grower is going to incur the application cost anyway then oil might as well be applied. Change in varieties effects use. Nonpareil, the main variety grown in California, is a soft shell variety, susceptible to insects, mites, and some diseases. Hard shell varieties are more resistant to insect damage, but have lower value.

The overall consensus is that Kern County has more in season insect problems (i.e. mites and San Jose scale) than the other regions of the state do. Kern County has a longer growing season, so there are four generations of San Jose scale instead of three. Growers in other areas observed that they did not usually have a San Jose scale problem on almonds and that early season mites are not bad on almonds. They began to experiment with dropping OP sprays. Many growers adopted the strategy of letting populations of mites and scale build up over a few years and then spraying to reduce costs and resistance to pesticides by target pests. Of course, there is an off-setting risk associated with this approach: mite and scale populations may reach levels difficult to control and result in lower average annual net profits than would result from annual spraying.

Growers adopted Bt after bloom once Bt products were available as an alternative to OP dormant sprays. However, Bt is now perceived by many to be too risky. In the mid 1990s, pyrethroids plus oil started to be used for control of PTB. This treatment offered longer control than Bt products did. The adoption of these alternatives may vary based on grower experience. Growers are always looking for new things to try but at the same time it can be very hard to convince them that a new treatment is better than, or at least as good, as their current one. New ideas are often tried on one row or small blocks. Almonds are a newer crop in Fresno county than in Merced county. It may easier to get new growers to start with a pesticide program that doesn't rely on OPs than it is to get established growers to change their traditional control programs.

Farm size may affect OP use. Growers in Kern county tend to be very large growers. Less than ten companies control 75 percent of the almond acres in Kern county. Managers make spray decisions trying to keep rejects down when their job performance evaluation includes reject levels attained. Spraying may be important for job retention. Large companies have in-house PCAs. For smaller growers there are more independent PCAs now and fewer chemical company representatives as chemical companies cut costs. This means that PCAs are not motivated to recommend sprays to sell chemicals and may be more likely to recommend soft programs to save their clients money. This information suggests that growers in Kern county are more likely to use OPs, as are large growers. Growers are concerned about the availability of OPs over time due to pesticide regulations and have tried to find alternatives before losing the materials. Thus, over time, any given grower would be less likely to apply OPs for relatively routine pest problems that can be controlled using alternatives. They would instead apply OPs only when there is a very serious pest problem.

Data and Variables

Our data contain two types of variables: variables regarding pesticide applications obtained from the California Department of Pesticide Regulation's Pesticide Use Reporting database, and variables regarding prices, production, inventories, weather, and other economic and physical factors that may affect OP use.

Each observation specifies the application year. Each year consists of a dormant season, from November 1 to March 20, and a growing season from March 21 through October 30. The 1991-1992 to 2000-2001 years are included. We have information for November 1 to December 31, 2001, but omit these observations from our analysis, because the entire season isn't reported. Each grower has a unique identification number for the PUR database, and an annual number of almond acres planted. The grower's total acres to which he reported applying each specific pesticide are also included. Applications of all pesticides are reported by date meaning that dormant season and growing season use are reported separately.

Weather variables for two time periods are included: the full dormant season (November 1 to March 20), and the critical dormant season (January 15 to February 15). Weather variables include total rainfall, the number of days with measurable precipitation (rain days), average daily temperature, average minimum daily temperature, cumulative chilling hours with a 30 degree threshold, and cumulative chilling hours with a 40 degree threshold. Weather variables were calculated from the National Weather Service data.

We aggregate counties into four growing regions intended to reflect differences in pest pressure, microclimate, and other factors. Kern county is treated as its own region. Fresno and Tulare counties are aggregated into the south region. San Joaquin, Stanislaus, Yolo, Madera, and Merced counties are aggregated into the central region. Butte, Colusa, Glenn, Sutter, and Tehama counties are aggregated into the north region.

Our data include a number of economic variables. We calculate an annual price measure for OPs, pyrethroids, carbamates, oils, and Bt. Prices for individual products within each class are weighted by the recommended label application rate per acre. The prices per pound for products were obtained from the CDPR mill tax database. The application rates were obtained from pesticide registration information. Almond price and quantity information was obtained from the California Almond Board. The current and lagged prices of almonds, carry-in from the previous year, and carry-out to the next year are included for each year as well as the state aggregate pounds of almonds rejected for the current and previous year. Annual almond production is reported separately by county for the current and lagged year.

One specific project objective was to develop means of testing whether or not pest management education programs had a significant effect on pesticide use. Arguably, the most important research and educational effort directed at developing a promoting adoption of alternatives to dormant OP use is the Biologically Integrated Orchard Systems (BIOS) program resulting from a collaboration among the Community Alliance with Family Farmers, a nonprofit organization, growers, licensed pest control advisers, University of California Cooperative Extension researchers, and DPR. The outreach program included publications, workshops, and field demonstrations open to the public. The BIOS program was in effect from 1993 – 1997 in Merced county, 1994 – 1998 in Stanislaus, and 1995 – 1999 in Madera, San Joaquin and Colusa counties. We created two variables related to BIOS. The first variable, BIOS, is a dummy variable for which counties and years the program was in effect. This variable is designed to test the direct effect of the program on OP use. The second variable, BIOSbeg, tests for lasting effects of the program. It is a dummy variable for counties in which the program was conducted for all years after the beginning of the program. For example, if BIOS was initiated in 1995 and terminated in 1998, the BIOS variable separates 1995-1998 from 1991 to 1994 and 1999-2000. The BIOSbeg variable would separate 1995-2000 from 1991 to 1994.

Empirical Analysis

In order to test our hypotheses, we completed three sets of regressions. The first set of regression examined whether or not individual producers chose to use OPs in a given year. Producers were considered OP users if they used any OPs at all. The second set of regressions examined the acres to which individual producers applied OPs in a given year. The third set examined application rates. Because the average reported application rate was roughly half the recommended label rate for OPs, we decided to examine whether or not we could identify any significant determinants of this decision. In order to examine the robustness of our findings regarding specific variables, we examined a number of regression specifications. When the sign and magnitude of the coefficient on a variable was consistent across model specifications, then we consider our finding robust. We also examined a number of model specifications because many of our variables were highly correlated, so that they could not be used in the same specification. We report the major findings. Additional model results are available from the authors.

Probability of Any Organophosphate Use: Probit Analysis. We first examined the decision to use any organophosphates in a particular year (Table 1). We used a probit regression to analyze the OP use decision. A probit allows us to examine the factors determining a yes-no decision, in this case OP use. The coefficients report the change in the probability that a grower will not use OPs in a specific year.   For example, in Table 1a in model 1, the coefficient on time indicates that for a given producer, each year he was 14% less likely to use OPs, holding other variables constant.

Most of our explanatory variables were significant, and of the expected sign. The time trend variable significantly reduced OP use, except in most models where input prices and lagged rejects were included as explanatory variables. The Kern County and South Region dummy variables significantly increased OP use in all models, relative to the North Region baseline. The Central Region dummy variable significantly reduced OP use. The previous year's price of almonds increased OP use, and was highly significant. This implies that growers expect a high price last year to translate into a higher price this year. However, this is contradicted by the effect of the carry-in inventory. Beginning inventory significantly increased OP use in all models. At first glance, this effect seems to contradict our prediction. A high beginning inventory will lower this year's price, other factors equal. A lower price reduces the returns to applying OPs. However, a high carry in also signals a large crop from the previous year and a short crop in the coming year. The price increase from the short crop is expected to outweigh the price decrease from the carry in. As predicted, the previous year's share of rejects significantly increased OP use. Current year Japanese exports significantly increased OP use, as predicted, although the magnitude of the effect was quite small. However, current year total exports significantly decreased OP use.

When significant, OP and pyrethroid price variables had the opposite signs from the predictions derived from economic theory. A higher OP price was significantly associated with a higher probability of OP use, and a higher pyrethroid price was significantly associated with a lower probability of OP use. The Bt price variable was highly significant and had the predicted sign: a higher Bt price was significantly associated with a higher probability of OP use.

The high correlation among weather variables limited our use of them in our model specifications. We report results for models using the full and short-season inches of rainfall variable. When significant, more inches of rain over the entire season tended to reduce the probability of OP use.

The BIOS program consistently reduced the probability that a producer used OPs. The BIOS variable, which evaluates the effect that the program had when it was active, had a larger coefficient than the BIOSbeg variable, which evaluates the effect the program had when it was active and after it ended.

Organophosphate Use in Acres: Tobit Analysis. The second set of regressions examined the determinants of the number of acres to which a grower applied OPs. These results were much more sensitive to the exact model specification than the probit results were (Table 2). Total almond acres had a consistently positive and significant effect, although it was small in magnitude. The time trend variable was negative and significant only when carry in was excluded.

Region was an important determinant of application acres, consistent with differences in farm sizes. Growers in the central region applied OPs to significantly fewer acres than growers in the northern region did. Growers in Kern county applied OPs to significantly more acres than growers in the northern region did. Growers in the south region applied OPs to more acres than growers in the northern region did, although the difference was not always significant. Other economic variables did not have the predicted effects. The lagged almond price was never significant. Carry-in had a positive effect on acres. The effect was significant unless the exports variable was included (model 2-11).   Pesticide prices did not have significant effects. The BIOS program variables were not significant for any specification; these results are not reported here.

Organophosphate Application Rate: Tobit Analysis. We performed a third set of regressions analyzing the determinants of the rate at which OPs were applied (Table 3). This analysis was motivated by our descriptive statistics analysis, which found that the mean application rate for non-zero OP applications was 1.82 pounds per acre, or approximately half the recommended label rate of four pounds per acre. Given the size of this difference, it seems unlikely that the difference was due entirely to data entry errors. For our regression analysis, we excluded observations where the calculated rate was less than 0.25 pounds per acre, or more than 30 pounds per acre. This excluded 172 of the 13,577 non-zero application observations.

The time trend variable was significant and positive in specifications that excluded input prices. This may be a result of growers choosing to apply OPs only when there is a serious pest problem in recent years, instead of the routine use of OPs early in the period analyzed. Farms with more total almond acres used significantly lower application rates than those with fewer acres, although the effect is small in magnitude. There were significant regional differences in the application rate. Growers in the south region and Kern County used significantly higher application rates than growers in the north region. Growers in the central region had application rates that were not significantly different.

Economic variables largely had the predicted effects, with the exception of carry-in stocks. The lagged price of almonds had a positive and significant effect on the application rate, as predicted, except when both carry-in and exports were included. In those models, it was insignificant and negative (models 3-27 and 3-28). Contradicting our prediction, carry-in levels had a positive significant effect as well. Lagged rejects as a share of production had a large positive statistically significant effect on the application rate, as predicted. Total exports and Japanese exports had significant and positive effects, as predicted, although they were very small in magnitude. Consistent with our prediction, the price of pyrethroids had a positive and weakly significant effect on OP use. However, the price of OPs and the price of Bt were not significant.

This analysis provided evidence that the BIOS program reduced OP use. While the BIOS variable was significant for most specifications, the BIOSbeg variable was highly significant for all model specifications.

Summary. Overall, the results suggest the following organophosphate use decision process. Growers are more likely to use OPs in years where rejects were a larger share of the previous year's harvest. Over time, growers are less likely to choose to use OPs. In addition, growers were less likely to use OPS when the BIOS program was in effect, with some program influence remaining after the program period. Provided growers choose to use OPs, the acreage to which OPs were applied was largely a function of almond acres, the region, and time, and was not influenced by the BIOS program or economic variables. In contrast, application rates for growers who chose to use OPs were affected by economic variables and the BIOS program. Interestingly, time had a positive effect on application rates. This is consistent with producer education measures encouraging growers to limit OP use to serious pest problems.

Lessons for Using Trend Analysis

Based on our analysis, CDPR could improve its understanding of the forces behind pesticide use trends by adding other variables to the analysis. First, CDPR already has access to pesticide price data through the mill tax database. While this data is less than ideal, due to inventory problems and the differences between wholesale and retail prices, it does provide a consistent price time series. Price information can be paired with the application rate label recommendation in order to obtain a per-acre cost of treatment. Although this variable did not perform well in our analysis, it may do so for other commodities and chemical classes, and for cases where a more accurate variable can be developed. Second, CDPR should continue its use of weather data from the national weather service. Third, CDPR could obtain data regarding commodity production and prices from the California Department of Food and Agriculture. Commodity groups, the California Almond Board in this case, can provide additional information regarding other factors likely to affect prices and pesticide use, such as inventories and quality measures, such as rejected pounds. Fourth, CDPR should examine the decision to use a given pesticide at all, and the choice of application rate, as well as the acreage to which a pesticide is applied, in order to evaluate use trends. Our analysis suggests that the acreage decision is the one least likely to show the influence of economic considerations. However, this may not be the case for other crops and pesticides.

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Table 1a. Determinants of the OP use decision: probit analysis.
(1=no OP use. 0=any OP use)

Model	2	3	5	6	14	15
Intercept	-0.40*** (0.022)	-0.41*** (0.022)	0.03 (0.042)	0.01 (0.042)	-0.40*** (0.078)	-0.40*** (0.078)
Time	0.14*** (0.0024)	0.14*** (0.0024)	0.013*** (0.0030)	0.13*** (0.0031)	0.089*** (0.0051)	0.090*** (0.0051)
Japan Exports						
Lagged Price			-0.00085*** (0.00014)	-0.00088*** (0.00014)	-0.0026*** (0.00024)	-0.0026*** (0.00024)
Carry In			-0.0015*** (0.00015)	-0.0014*** (0.00015)	-0.0026*** (0.00022)	-0.0025*** (0.00022)
Exports					3.76E-6*** (3.065E-7)	3.65E-6*** (3.07E-7)
Rainfall 11/1 – 3/20					-0.00059*** (0.000092)	-0.00058*** (0.000092)
Kern	-0.52*** (0.032)	-0.51*** (0.032)	-0.53*** (0.032)	-0.51*** (0.032)	-0.68*** (0.047)	-0.66*** (0.048)
Central	0.11*** (0.020)	0.12*** (0.021)	0.11*** (0.020)	0.12*** (0.021)	0.070** (0.031)	0.091*** (0.032)
South	-0.32*** (0.026)	-0.30*** (0.026)	-0.32*** (0.026)	-0.30*** (0.026)	-0.43*** (0.042)	-0.41*** (0.042)
BIOS	0.93*** (0.31)		1.01*** (0.31)		1.10*** (0.31)	
BIOSbeg		0.32*** (0.076)		0.32*** (0.077)		0.34*** (0.078)
Log Likelihood	-22,586	-22,583	-22,513	-22,511	-17,234	-17,233

*** Significant at the 1% level
** Significant at the 5% level
* Significant at 10% level

Table 1b. Determinants of the OP use decision: probit analysis.

(1=no OP use. 0=any OP use)

Model	24	25	26	30
Intercept	1.15*** (0.29)	1.09*** (0.29)	1.08*** (0.29)	-1.42*** (0.26)
Time	0.02 (0.023)	0.024 (0.023)	0.024 (0.023)	0.23*** (0.024)
Lagged Rejects	-0.043*** (0.0062)	-0.044*** (0.0062)	-0.043*** (0.0062)	
OP price	-0.036*** (0.0033)	-0.036*** (0.0033)	-0.036*** (0.0033)	-0.0022 (0.0040)
Pyrethroid Price	0.0064*** (0.00065)	0.0063*** 0.00066	0.0062*** (0.00066)	0.0031*** (0.00050)
Bt Price	-0.13*** (0.018)	-0.12*** (0.018)	-0.12*** (0.018)	0.056*** (0.019)
Rainfall 11/1-3/20	0.00025** (0.000099)	0.00029*** (0.000010)	0.00029*** (0.000010)	
Japan Exports				-0.000013*** (1.56E-6)
Kern	-0.42*** (0.050)	-0.40*** (0.050)	-0.37*** (0.051)	-0.50*** (0.037)
Central	0.25*** (0.034)	0.27*** (0.035)	0.30*** (0.035)	0.19*** (0.025)
South	-0.18*** (0.045)	-0.16*** (0.046)	-0.13*** (0.047)	-0.26*** (0.031)
BIOS		1.09*** (0.31)		
BIOSbeg			0.39** (0.078)	
Log Likelihood function	-14,737	-14,730	-14,724	-14,732

*** Significant at the 1% level
** Significant at the 5% level
* Significant at 10% level

Table 2. Determinants of the OP acreage decision: tobit analysis

Model	3	4	5	9	11
Intercept	3.80*** (0.025)	3.80*** (0.033)	3.73*** (0.047)	3.61*** (0.067)	3.70*** (0.11)
Time	-0.0072*** (0.0028)	-0.0074** (0.0030)	-0.0029 (0.0037)	-0.0027 (0.0037)	-0.0062 (0.0058)
Acres Planted	0.0030*** (0.000042)	0.0030*** (0.000042)	0.0030*** (0.000042)		0.0029*** (0.000049)
Central	-0.20*** (0.022)	-0.20*** (0.022)	-0.20*** (0.022)	-0.16*** (0.028)	-0.27*** (0.037)
South	0.052* (0.027)	0.053* (0.027)	0.053** (0.027)	0.11*** (0.034)	-0.012 (0.048)
Kern	0.26*** (0.031)	0.263*** (0.031)	0.26*** (0.031)	0.32*** (0.039)	0.20*** (0.053)
Lagged Rejects					0.0091* (0.0050)
Lagged Price		0.000026 (0.00017)	6.11E-6 (0.00017)	9..48E-6 (0.00017)	
Rainfall 11/1 – 3/20				0.00021** (0.000082)	-0.000018 (0.00012)
Exports					6.54E-9 (3.18E-7)
Carry In			0.00034** (0.00016)	0.00050*** (0.00017)	0.00037 (0.00027)
(Scale)	0.84 (0.0060)	0.84 (0.0060)	0.84 (0.0060)	0.84 (0.0060)	0.85 (0.0074)
Log Likelihood function	-18,344	-18,344	-18,342	-18,339	-12,727

*** Significant at the 1% level
** Significant at the 5% level
* Significant at 10% level

Table 3a. OP application rate: tobit analysis

Model	14	15	17	18	27	28
Intercept	0.59*** (0.026)	0.60*** (0.026)	0.51*** (0.028)	0.52*** (0.028)	0.47*** (0.047)	0.47*** (0.047)
Time	0.016*** (0.0022)	0.016*** (0.0022)	0.0087*** (0.0023)	0.0088*** (0.0023)	-0.0067* (0.0035)	-0.0071** (0.0035)
Central	-0.019 (0.014)	-0.027** (0.014)	-0.018 (0.014)	-0.026* (0.014)	-0.015 (0.017)	-0.027 (0.017)
South	0.083*** (0.017)	0.075*** (0.017)	0.088*** (0.016)	0.080*** (0.017)	0.075*** (0.020)	0.063*** (0.021)
Kern	0.13*** (0.019)	0.12*** (0.019)	0.14*** (0.019)	0.13*** (0.019)	0.091*** (0.023)	0.078*** (0.024)
BIOS	-0.79** (0.37)		-0.75** (0.37)		-0.71* (0.38)	
BIOSbeg		-0.30*** (0.065)		-0.32*** (0.065)		-0.33*** (0.068)
Acres Planted	-4.6E-5*** (7.13E-6)	-4.6E-5*** (7.13E-6)	-4.4E-5*** (7.16E-6)	-4.4E-5*** (7.16E-6)	-3.8E-5*** (8.39E-6)	-3.8E-5*** (8.40E-6)
Carry In	0.00034*** (0.00010)	0.00033 (0.00010)	0.00026** (0.00010)	0.00025** (0.00010)	0.00030** (0.00015)	0.00027* (0.00015)
Lagged Price			0.00080*** (0.00011)	0.00081*** (0.00011)	-0.000077 (0.00017)	-0.000075 (0.00017)
Exports					7.80E-7*** (1.98E-7)	8.33*** (1.98E-7)
(Scale)	0.53 (0.0025)	0.53 (0.0025)	0.52 (0.0026)	0.52 (0.0026)	0.54 (0.0032)	0.54 (0.0032)
Log Likeli-hood	-9,957	-9,950	-9,929	-9,920	-6,951	-6,942

*** Significant at the 1% level
** Significant at the 5% level
* Significant at 10% level

Table 3b. OP application rate: tobit analysis

Model	23	25	32	33	34
Intercept	0.54*** (0.031)	0.58*** (0.031)	0.60*** (0.082)	0.60*** (0.082)	0.60*** (0.082)
Time	0.015*** (0.0019)	0.00010 (0.0026)	-0.0070** (0.0085)	-0.0070 (0.0085)	-0.0073** (0.0085)
Central	-0.018 (0.014)	-0.014 (0.017)	-0.011* (0.017)	-0.012 (0.017)	-0.024 (0.017)
South	0.085*** (0.017)	0.078*** (0.020)	0.080*** (0.020)	0.079*** (0.020)	0.067*** (0.021)
Kern	0.13*** (0.019)	0.094*** (0.023)	0.094*** (0.023)	0.094*** (0.024)	0.081*** (0.024)
BIOS	-0.80** (0.37)			-0.72 (0.39)	
BIOSbeg					-0.32*** (0.068)
Acres Planted	-0.000045*** (7.20E-6)	-0.000038*** (8.42E-6)	-0.000038*** (8.52E-6)	-3.8E-5*** (8.52E-6)	-3.8E-5*** (8.53E-6)
Japan Exports		4.034E-6*** (6.36)			
Lreratio	4.10*** (0.96)		2.88** (1.37)	2.92** (1.37)	2.85** (1.37)
Op price			0.0021 (0.0014)	0.0021 (0.0014)	0.0021 (0.0014)
Pyrethroid price			0.00039* (0.00021)	0.00038* (0.00021)	0.00045** (0.00021)
Bt price			-0.0013 (0.0039)	-0.0013 (0.0039)	-0.0014 (0.0039)
(Scale)	0.53 (0.0026)	0.54 (0.0032)	0.55 (0.0032)	0.54 (0.0032)	0.54 (0.0032)
Log Likelihood function	-9,919	-6,952	-6,930	-6,929	-6,921

*** Significant at the 1% level
** Significant at the 5% level
* Significant at 10% level

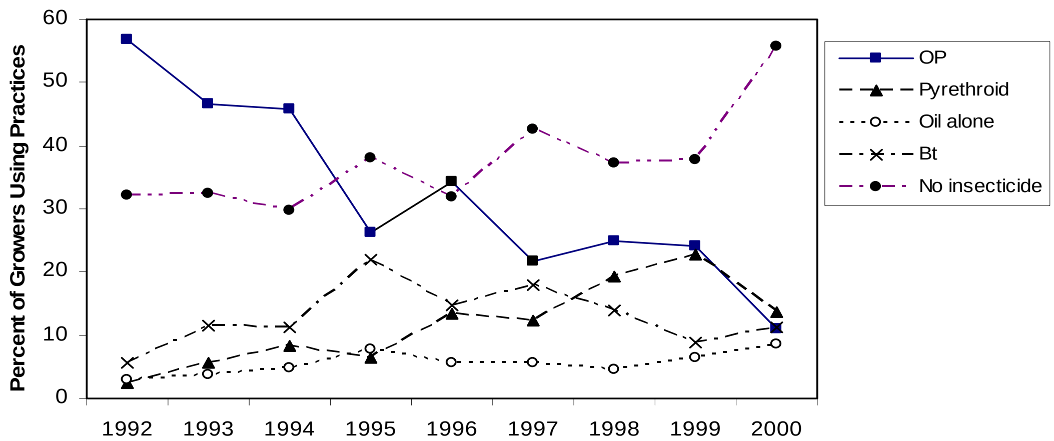

Figure 1. Percent of Growers Using Dormant Season Control Practices

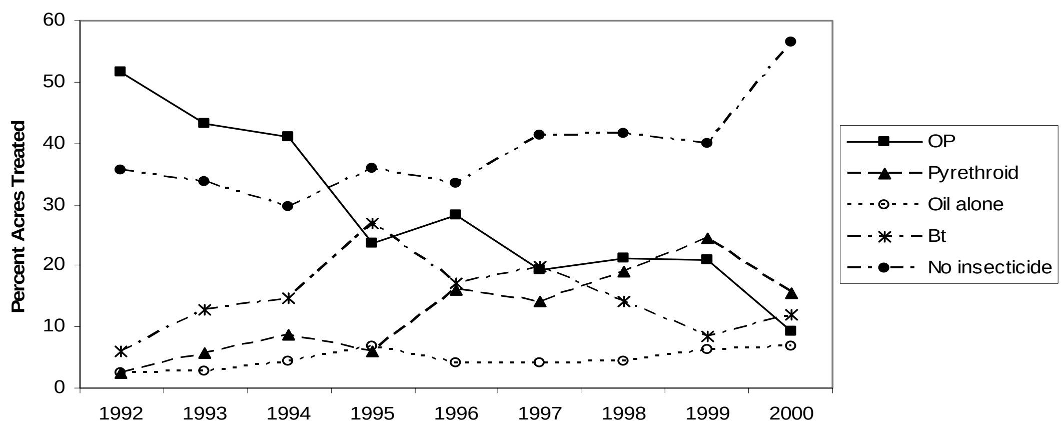

Figure 2. Percent of Acres Treated with Dormant Season Control Practices

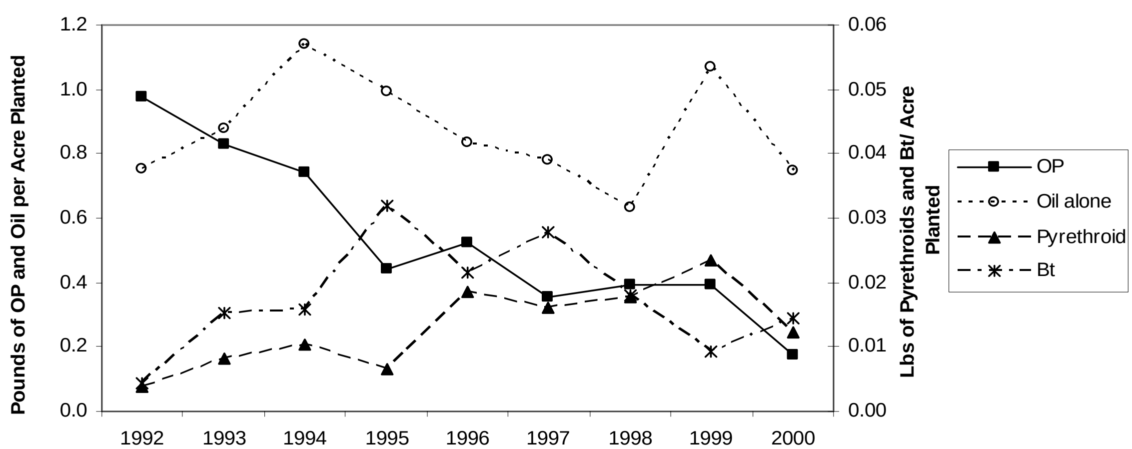

Figure 3. Average Pounds Applied per Acre of Alternative Pesticides