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SUBJECT: EVALUATION OF OPTIONS AND RECOMMENDATIONS FOR REDUCING VOLATILE ORGANIC COMPOUND EMISSIONS FROM NONFUMIGANT PESTICIDES

Summary

Volatile organic compounds (VOCs) contribute to the formation of ground-level ozone, a major air pollutant. The federal Clean Air Act (CAA) requires a State Implementation Plan (SIP) for regions that do not achieve the ozone air quality standard (nonattainment areas [NAAs]). California's SIP includes an element that requires the Department of Pesticide Regulation (DPR) to track and reduce pesticidal sources of VOCs in five NAAs during the May-October period. DPR maintains an emission inventory to track pesticide VOC emissions, based on the amount of pesticide products applied (from pesticide use reports) and the VOC content (emission potential [EP]) of pesticide products. The emission inventory indicates that DPR will consistently achieve the SIP reduction goals for four of the five ozone NAAs, but may not consistently achieve the SIP reduction goal for the San Joaquin Valley (SJV) NAA because of the relatively large contribution of nonfumigant VOC emissions to total pesticidal emissions.
Pesticide products containing abamectin, chlorpyrifos, gibberellins, or oxyfluorfen are among the highest nonfumigant VOC contributors in the SJV. Products with lower VOC emissions are

available for these active ingredients (A.I.s), but current voluntary efforts to use lower VOC products may not consistently achieve the SIP reduction goals during high pesticide use years.

DPR can set VOC emission thresholds for nonfumigant products based on the EP to designate products as "low-VOC" or "high-VOC." DPR will consistently achieve the SIP reduction goal for the SJV by prohibiting when necessary the uses of high-VOC products during May-October. Low-VOC products need no VOC restrictions. The amount of VOC reductions achieved from nonfumigant restrictions depend on four factors: the pesticide products (by A.I.) included, the EP thresholds selected, the crops included, and the exceptions to the prohibitions.

The recommended option to enforce the nonfumigant VOC restrictions is implementing requirements only if pesticide VOC emissions exceed a trigger level for the SJV during May-October. Due to the lag in pesticide use reporting, restrictions are implemented for an upcoming year if pesticide VOC emissions exceeded the trigger level in a preceding year. If triggered, the restrictions would be enforced with notification requirements on the purchase of high-VOC products and/or a requirement to obtain a pest control adviser recommendation prior to using a high-VOC product. DPR should implement the nonfumigant VOC restrictions as sales and/or use regulations no later than April 2013 to avoid triggering a fumigant emission limit.

Background

DPR is legally obligated to track and reduce VOC emissions from pesticides.

VOCs contribute to the formation of ground-level ozone, which is harmful to human health and vegetation when present at high enough concentrations. The federal CAA requires each state to submit a SIP for achieving and maintaining federal ambient air quality standards, including the standard for ozone. NAAs are regions in California that do not meet ambient air quality standards. California's Air Resources Board (ARB) and DPR developed a plan to track and reduce pesticidal sources of VOCs in NAAs as part of the California SIP to meet the ozone standard. DPR is responsible for agricultural and commercial structural pesticide products, and ARB is responsible for pesticides in consumer products.

The current SIP approved by the U.S. Environmental Protection Agency (EPA) includes an element that requires DPR to maintain an inventory of VOC emissions from agricultural and structural pesticides for five ozone NAAs (Figure 1). The SIP also requires DPR to reduce pesticide VOC emissions by the following amounts, relative to the 1990 base year:

- 20 percent (%) reduction in Sacramento Metro by 2005
- 12% reduction in SJV by 1999
- 20% reduction in Southeast Desert by 2007
- 20% reduction in South Coast by 2010
- 20% reduction in Ventura by 2012

In 2009, DPR and ARB submitted a proposed SIP amendment to U.S. EPA that included two additional commitments. DPR committed to and has implemented regulations that require use of low emitting fumigation methods in the SJV. DPR also committed to implementing restrictions to reduce VOC emissions from nonfumigant pesticides by 2014 in the SJV. This SIP amendment also equates the 12% reduction for SJV to a total emission ceiling of an average of 18.1 tons/day during the May-October period.

DPR maintains an emission inventory to track pesticide VOC emissions, based on pesticide use reports, estimates of the VOC content in products, and fumigant monitoring data.

DPR prepares an annual estimate of VOC emissions from agricultural and commercial structural pesticide applications. There is an emission inventory for each year since 1990, the base year. Pesticide applications in five NAAs are included: Sacramento Metro, SJV, South Coast, Southeast Desert, and Ventura (Figure 1). Only agricultural and commercial structural pesticide applications are included. ARB tracks emissions from pesticides in consumer products. DPR uses data of VOC content and pesticide use to estimate emissions from reported agricultural and commercial structural applications in each NAA. The inventory focuses on May 1 through October 31, the peak ozone season in California.

To estimate the VOC contribution of individual agricultural and structural use pesticides, DPR multiples the fraction of a pesticide product estimated to be VOCs (its emission potential [EP]) by the amount of that product applied.

Estimated VOC emissions = (EP of the product) X (Pounds of pesticide product applied)

Pesticide use reports provide the amount of product used. California requires full reporting of all agricultural pesticide use and the use of pesticides by pest control businesses. The reports document the product applied, the amount applied, date applied, location (within a one square mile section), crop treated, number of acres treated, and other information.

DPR has several methods to determine product EPs. The preferred way is through laboratory analysis, using a standardized method approved by DPR (thermogravimetric analysis [TGA]). When it is not available, DPR uses other approaches to estimate EPs.

- Using the VOC EP already measured by TGA for an identical or nearly identical pesticide product.
- Using the confidential statement of formula on file with DPR to find out the percentage of water and other inorganic chemicals in the product. This is subtracted and the remainder is assumed to produce emissions that must be included in the inventory.
- Assigning an estimated value based on an evaluation of a product's unique chemistry and composition.
- Assigning a default EP at a representative level, based on TGA data of similarly formulated products (Table 1).

Table 1 shows the median EPs that are used as default values for the different formulation classes, based on TGA data. Pressurized products and emulsifiable concentrates have the highest EPs, and solid products (e.g., dusts, granules) have the lowest EPs.

Fumigant emissions are adjusted to account for how emissions vary with fumigation method (Application Method Adjustment Factor [AMAF], or emission rating). AMAFs have been determined from field study data and are A.I. and application method specific. Since the AMAFs are based on field measured data for specific application methods and fumigants, they yield more accurate estimates of fumigant VOC emissions than unadjusted emission estimates.

Estimated fumigant VOC emissions = lbs of product used x EP x AMAF

Nonfumigant product emissions are not currently adjusted for application method or other field factors due to a lack of data to support such adjustments.

The emission inventory indicates that DPR will consistently achieve the SIP reduction goals for four of the five ozone NAAs due to the fumigant regulations implemented in 2008.

As shown in Figure 2a – e, most pesticide VOC emissions are from fumigants and products formulated as emulsifiable concentrates. Fumigants are volatile pesticides, applied in relatively high amounts. Emulsifiable concentrates often contain volatile solvents that keep pesticides in liquid form, so that mixing and applying the product are easier. Figure 2a – e also shows that the Sacramento Metro and South Coast NAAs have consistently achieved the SIP goal of a 20% reduction from the 1990 base year. Prior to 2008, the SJV, Southeast Desert, and Ventura NAAs did not always meet the SIP reduction goals.

The VOC reductions in the SJV, Southeast Desert, and Ventura NAAs beginning in 2008 were primarily due to regulations DPR implemented that year for fumigants. The regulations required "low-emission" fumigation methods in those three NAAs during the May-October peak ozone season. The low-emission methods reduced the May-October fumigant VOC emissions by approximately one-third, and some users shifted applications outside the May-October ozone season, contributing additional reductions (Tables 2 and 3). The regulations also established a fumigant emission limit for the Ventura NAA because the low-emission methods may be insufficient to achieve the SIP reduction goal. The county agricultural commissioner (CAC) enforces the fumigant limit through an emissions allowance program or other means. Ventura's fumigant limit program is also a backstop measure for the other NAAs, and is implemented if pesticide VOC emissions exceed a trigger level of 95% of the SIP goal. Since fumigants contribute the majority of the pesticide VOC emissions in the Southeast Desert NAA, the fumigant limit backstop measure will ensure that this NAA will consistently achieve the SIP reduction goal.

The emission inventory indicates that DPR may not consistently achieve the SIP reduction goal for the SJV NAA due to nonfumigant VOC emissions.

A fumigant limit program is a less efficient reduction measure for the SJV because a majority of pesticide VOC emissions are from nonfumigants. As shown in Figure 2e, pesticide VOC emissions in the SJV NAA exceeded the SIP goal in 2005 and 2006. While the fumigant regulations reduced the fumigant emissions, the SIP goal would likely still have been exceeded had the fumigant regulations been in effect at the time. Additionally, the 2010 pesticide VOC emissions for the SJV were within approximately 1 ton/day of triggering a fumigant emission limit. The year-to-year variation in emissions is approximately 0.5 – 3 tons/day. Anecdotal information indicates that emissions in 2011 may be higher than 2010 (e.g., higher cotton acreage), possibly triggering a fumigant limit for 2013 in the SJV.

The current regulations may require additional fumigant reductions through a fumigant limit and allowance program, even though fumigants only account for approximately one-quarter of the pesticide VOC emissions in the SJV NAA. If nonfumigant emissions increase, it's possible that current regulations would require a major decrease or a total prohibition of fumigants, and still not achieve the pesticide SIP goal for the SJV. Restrictions on nonfumigant VOC emissions in the SJV NAA are needed to: (1) ensure that the SIP goal is achieved in a worst-case year; (2) reduce the regulatory burden on fumigants and avoid triggering a fumigant limit; and (3) comply with the SIP commitment to implement restrictions on nonfumigant pesticides by 2014.

Feasibility of Reducing VOC Emissions from Nonfumigant Pesticides

DPR is conducting a “reevaluation” to assess the reformulation of certain nonfumigant pesticide products.

In 2005, DPR initiated a reevaluation (regulatory process to request actions by pesticide manufacturers and formulators [registrants]) for several hundred nonfumigant products. The reevaluation required registrants to submit plans for reformulating the inert ingredients in the products to reduce product EPs, thereby reducing VOC emissions. Some registrants responded to the reevaluation or earlier informal DPR requests by successfully reformulating several products (Table 4). In 2010, DPR revised the reevaluation to limit reformulation efforts to the products with the highest pesticide VOC contribution in the SJV:

- Abamectin products (e.g. Agri-Mek®)
- Chlorpyrifos products (e.g. Lorsban®)
- Dimethoate products (e.g. Cygon®)
- Gibberellins products (e.g. Gibgro®)
- Oxyfluorfen products (e.g. Goal®)
- Permethrin products
- Trifluralin products (e.g. Treflan®)

For the reasons detailed below, DPR now proposes to focus VOC reductions on abamectin, chlorpyrifos, gibberellins, and oxyfluorfen products.

Pesticide products containing abamectin, chlorpyrifos, gibberellins, or oxyfluorfen are consistently among the highest nonfumigant VOC contributors in the SJV.

Table 5 and Figure 3 show that products containing abamectin, chlorpyrifos, gibberellins, or oxyfluorfen have consistently been among the highest pesticide VOC contributors in the SJV for several years. Combined, products with these four A.I.s accounted for 28% of the pesticide VOC emissions in the SJV during May-October 2008-2010. Products containing other A.I.s such as dimethoate, permethrin, and trifluralin were relatively high VOC contributors several years ago, but have declined recently. Conversely, pesticides that were relatively low contributors in earlier years have recently increased, such as products containing bifenthrin and fenpyroximate. The trends for the last several years may or may not continue in the future.

Products with lower VOC emissions are available for several major nonfumigant A.I.s.

In most cases, the most agronomically feasible alternatives to current emulsifiable concentrates are liquid products that contain the same A.I. Solid products such as dusts and powders have lower EPs (median EP = 1.5%) compared to emulsifiable concentrates (median EP = 39%), but different equipment and procedures are required to apply solid products. Consequently, simple substitution of solid formulations for liquid formulations may not be possible in many cases. However, liquid products containing abamectin, chlorpyrifos, or oxyfluorfen are available with lower EPs than other products commonly used containing these same A.I. (Table 6). Most of the liquid products with lower EPs have only recently been registered, and currently have low use. Abamectin, chlorpyrifos, oxyfluorfen, as well as gibberellins and other A.I. are also available in products formulated as solids (e.g., dusts, powder, granules). Reformulation for most other major pesticide VOC contributors is not feasible because the products contain little or no VOCs as inert ingredients (fumigants, oils, and acrolein) or the EPs are already relatively low (glufosinate, glyphosate, and oil products have EPs less than 15%).

The agricultural impact of switching to products with lower VOC emissions is minimal in some cases.

The major nonfumigant VOC contributors have different uses in the SJV during May-October. Abamectin is a miticide and insecticide used on a wide variety of crops, but mostly almonds. Chlorpyrifos is an insecticide used primarily on alfalfa, almonds, citrus, cotton, and walnuts. Gibberellins are growth regulators used primarily on citrus and grapes. Oxyfluorfen is an herbicide used primarily on almonds and pistachios. Use of abamectin, chlorpyrifos, gibberellins, and oxyfluorfen products with lower VOC emissions likely has lower agricultural impact (greater relative efficacy and lower additional cost) compared to other major nonfumigants. Under contract to the California Department of Food and Agriculture (CDFA), the University of California (UC) evaluated the cost and efficacy of alternatives with lower VOC emissions for the major pesticides used on selected crops, including alfalfa, almonds, broccoli, cotton, grapes, lettuce, oranges, and walnuts (Appendix 1). In general, the effective alternatives with lower VOC emissions for abamectin, chlorpyrifos, gibberellins, and oxyfluorfen had lower cost than the other major nonfumigants (Table 7a – b). However, the alternatives with lower VOC emissions were not as effective as products with higher VOC emissions for some crops and pests. More information on efficacy and costs of switching to products with lower VOC emissions is given in later sections.

Current voluntary efforts assist in reducing nonfumigant VOC emissions, but may not consistently achieve the SIP reduction goals.

The U.S. Department of Agriculture – Environmental Quality Incentives Program (USDA-EQIP) provides matching funds to growers for precision sprayers, fumigant water treatments, and nonfumigant products with lower VOC emissions.

DPR has developed several tools to assist growers in using low-VOC alternatives. DPR has written a guide that describes low-VOC options (<http://www.cdpr.ca.gov/docs/emon/vocs/vocproj/reducing_voc_emissions.pdf>). DPR has developed a calculator for growers and applicators that determines the VOC emissions of nonfumigant products after inputting the product, application rate, and acres (<http://apps.cdpr.ca.gov/voc-calculator>).

These and other voluntary efforts to switch to products with lower EPs have had limited success. Figure 4 shows the time trend of pounds of VOCs for each pound of A.I. applied in the SJV. Abamectin (until 2010) and chlorpyrifos show a decline in the pounds of VOCs per pound of A.I. in recent years, indicating that their products with lower EPs are being adopted. However, Figure 3 shows that changing to products with lower EPs was offset by greater use of the products, and overall emissions (EP x use) from abamectin and chlorpyrifos products increased between 2009 and 2010. In contrast, the pounds of VOC per pound of A.I. for gibberellins and oxyfluorfen have remained constant or increased in recent years, indicating that their products with lower EPs are not being adopted.

Regulatory Issues and Options: Strategy and Scope for Reducing Nonfumigant VOC Emissions

DPR should set VOC emission thresholds for products containing certain A.I.s.

DPR should set a different emission threshold for different A.I.s. Products exceeding the thresholds would be subject to additional sales or use restrictions. Two types of emission thresholds are possible.

DPR can set a VOC emission threshold for nonfumigant products based on the VOC EP and/or VOC emission rate to designate products as “low-VOC or “high-VOC.”

Similar to ARB’s consumer products program, DPR can set EP thresholds for products containing certain A.I.s. Alternatively, or in addition, DPR can set emission rate thresholds (pounds VOC/acre; EP x maximum product application rate). (NOTE: the emission rate in this context is based on laboratory TGA data and is not intended to adjust emissions for field conditions.) DPR can set different product emission thresholds for each A.I., based on the product(s) with the lowest EP or emission rate. Alternatively, DPR can set emission thresholds based on achieving certain target VOC emission reductions. DPR would set a separate emission threshold for each A.I. affected. DPR would designate products complying with the emission thresholds as low-VOC and products not complying with the emission thresholds as high-VOC.

Setting product emission rate thresholds should be considered if there are products that have been reformulated to increase the amount of A.I., without significantly changing the content or amounts of the solvents in the products. In these cases, the EPs may not have changed significantly, but the label would require a lower product application rate to achieve the same A.I. application rate. This would result in lower overall VOC emissions because less product would be applied. No currently registered products are candidates for setting an emission rate threshold.

Setting the emission thresholds based on the currently available product(s) with the lowest EP or emission rate is easier to determine and implement than setting thresholds based on a target VOC reduction (e.g., reduce VOC emissions by one ton per day). Setting a threshold based on a target VOC reduction could result in thresholds too low to be achieved with current technology. Conversely, it could also result in thresholds that are too easy to achieve, penalizing registrants who have already reformulated to a lower EP. While it would be relatively easy to determine an overall target VOC reduction amount, DPR would also need to make subjective judgments about sub-targets to achieve for each A.I.

Currently registered products containing abamectin, chlorpyrifos, gibberellins, or oxyfluorfen provide clear choices for designating low-VOC and high-VOC products.

Growers and applicators generally prefer liquid products over solid products due to the handling and mixing characteristics. However, liquid products generally have higher EPs. If feasible, the product emission thresholds should be based on liquid products that have relatively low EPs to reduce the agricultural impact. Additionally, the product emission thresholds should be set so that several registrants have products that achieve the threshold to avoid major market disruptions.

Abamectin, chlorpyrifos, and oxyfluorfen have several liquid products available with lower EPs (Table 8). There are two distinct EP groups for both chlorpyrifos and oxyfluorfen, and three for abamectin.

- Five chlorpyrifos liquid products from three registrants have EPs less than 21%. The remaining chlorpyrifos liquid products have EPs of 50% or greater.
- Six oxyfluorfen liquid products from four registrants have EPs less than 11%. The remaining oxyfluorfen liquid products have EPs of 60% or greater.

- Two abamectin liquid products from a single registrant have EPs of approximately 6%. Three liquid products from two other registrants have EPs of approximately 30%. All other abamectin liquid products have EPs of 55% or greater. An abamectin EP threshold of 10% would achieve the most VOC reduction, but this could cause market disruptions because products would only be available from a single registrant. An abamectin EP threshold of 35% would be less stringent and achieve less VOC reduction, but have less market disruption.

Gibberellins lack liquid products with lower EPs, but several solid formulations are available, all with EPs of less than 5% (Table 8c). All gibberellins liquid products have EPs of at least 79%, but a new liquid product in development will likely have an EP of approximately 20%. An EP threshold of 5% for gibberellins would achieve the most VOC reduction, but there are handling and mixing problems with some applications of the solid products (Appendix 1). An EP threshold of 25% for gibberellins would allow the opportunity to develop liquid low-VOC products, but this could cause market disruptions if only one registrant successfully reformulates to this level. In the short-term, either EP threshold (5% or 25%) would result in the same VOC reduction because there are no gibberellins products currently available with an EP between 5 and 25%.

As discussed above, products containing abamectin, chlorpyrifos, gibberellins, or oxyfluorfen are consistently among the top nonfumigant VOC contributors in the SJV. Setting emission thresholds for only these pesticides could provide incentive for growers to switch to other A.I.s with products that have higher VOC emissions, negating the anticipated VOC reductions. Setting emission thresholds for numerous A.I.s and products would achieve greater VOC reductions, but administering such a large program would greatly increase DPR's workload, and likely cause unwanted effects such as efficacy problems with some crops. At least initially, DPR could never be certain that it included all of the possible alternatives, and not all of the alternatives have a low-VOC product available. If growers do not change to other A.I.s, the needed VOC reductions can be achieved from a few A.I.s, as discussed in a later section.

DPR should consider excluding some nonfumigant products and uses from any VOC restrictions.

Some products containing abamectin, chlorpyrifos, gibberellins, or oxyfluorfen also contain other A.I.s. Emission thresholds should only be set for products based on the "primary A.I." If a product contains more than one A.I., the primary A.I. is the one present at the highest percentage in a product. The specific inert ingredients and amounts greatly depend on the solubility and other characteristics of the A.I.s. A product emission threshold based on the primary A.I. may be infeasible for products that contain the pesticide, but as a secondary A.I.

DPR is obligated to reduce VOC emissions from agricultural and structural pesticide uses. However, DPR should consider exempting structural and non-production agricultural (e.g., cemetery, right of way, golf course) uses from these regulatory actions. As shown in Table 9 these uses have negligible emissions and some of the enforcement options discussed below are problematic for these uses.

Table 10 shows the VOC emissions for abamectin, chlorpyrifos, gibberellins, and oxyfluorfen products by crop for the SJV. These A.I.s are used for several dozen crops. However, commodities such as almonds that have high acreage contribute the most VOCs from these products, and the top ten crops account for more than 90% of the emissions from these pesticide products. DPR should consider exempting most of the minor crops because they have low emissions and the efficacy of the low-VOC products is uncertain in many cases.

An analysis by the UC indicates that low-VOC products are not as effective as high-VOC products in some instances (Appendix 1). Examples include:

- Low-VOC products are not as effective for cotton and corn aphids.
- Additional application of other herbicides at low application rates may be needed for low-VOC oxyfluorfen to be effective for some post-emergence situations.
- Low-VOC (dust/powder) gibberellins are difficult to apply at low application rates.

There may be other situations where low-VOC products have uncertain efficacy or other problems, particularly for specialty crops.

Certain products and uses are exempted from registration under Section 18 or have a Special Local Need registration under Section 24(c) of the Federal Insecticide, Fungicide, and Rodenticide Act. These applications usually have low use because they are used to control unusual pests or for unusual crops. The efficacy of low-VOC products is uncertain for these atypical applications. The only current applicable Section 18 exemption is for abamectin on lima beans. The current applicable Section 24(c) registrations are for:

- Abamectin on alfalfa
- Chorpyrifos on citrus
- Gibberellins on azaleas and tangerines
- Oxyfluorfen on almonds, clover, olives, peas, roses, and stone fruit

A second use category includes pesticide applications required by USDA, CDFA, or CACs to eradicate or control exotic pests. These agencies have extensive activities to prevent establishment of invasive pests that do not normally occur in California. Federal and state laws require quarantines and other measures to contain and eradicate certain detected pests. Pesticide applications soon after detection are often successful in avoiding greater pesticide use if the exotic pest becomes established. Low-VOC products may or may not be effective for exotic pests.

DPR should also consider exemptions for situations where the efficacy of the low-VOC products is uncertain or lower than the high-VOC products. If DPR required low-VOC products in all cases, growers and applicators would likely use a greater amount of product, offsetting any VOC reductions from the lower EPs. More importantly, the amount of A.I. applied would likely increase. The health and environmental risk of a greater amount of A.I. could easily outweigh the benefits of any VOC reductions that might be achieved.

DPR should consider exceptions to high-VOC restrictions for reasons other than efficacy. For example, “smart sprayers” use various sensing technologies to treat only the target plant or pest. The sprayer is automatically turned off when a target plant or pest is not detected. Smart sprayers apply less pesticide product to achieve the same efficacy. This has the same effect as using a low-VOC product, with the added benefit of applying less A.I.

To ensure the SIP reduction goal is achieved, DPR may need to offset the exclusions and exceptions to nonfumigant VOC restrictions with more stringent requirements for other uses. However, for situations where it is uncertain if an exception is needed, DPR should usually include rather than exclude the exception from the regulations. Adding exceptions once the regulations go into effect could be infeasible, even if unequivocal evidence demonstrates efficacy or other problems at a later date. The federal CAA prohibits making regulations less stringent (backsliding) once they are in effect. Adding exceptions to high-VOC restrictions might be considered backsliding. At a minimum, DPR would need to demonstrate that the SIP reduction goal will still be achieved with the added exceptions. DPR should consider implementing regulations that achieve more reductions than legally required to allow exceptions in the future. Alternatively, it may be possible to add exceptions if additional restrictions are enacted at the same time to offset the exceptions.

DPR only needs nonfumigant VOC restrictions for the SJV during May-October.

While other areas of the state do not meet the federal air quality standard for ozone, the regulatory options discussed here for the SJV are inappropriate for statewide restrictions or other NAAs for several reasons.

- SJV is the only NAA for which additional pesticide VOC reductions may be needed to achieve the SIP goal. The other four NAAs included in the pesticide SIP element consistently achieve SIP goals.
- Most of the top nonfumigant VOC contributors in the SJV NAA are not top contributors in the other NAAs. If needed, nonfumigant VOC restrictions for other areas should focus on products with different A.I.s and different crops.

- DPR can develop similar restrictions for other areas in the future if it becomes necessary. However, if DPR were to put restrictions in place now, they would have to stay in place even if not necessary because making the regulations less stringent in the future is not allowed by the anti-backsliding provisions of the federal CAA.
- Extending restrictions outside the SJV would likely not comply with the Administrative Procedures Act because they would cause an unwarranted regulatory burden in other regions.

Similarly, DPR should require the nonfumigant VOC restrictions only during May-October instead of year-round for several reasons.

- May-October is the peak ozone season and the time period of the SIP goal as well as the time period included in DPR's emission inventory. VOC reductions outside May-October would have no effect on compliance with the SIP goal or emission inventory.
- The restrictions will likely have the added benefit of reducing emissions by shifting applications outside the May-October period. Table 3 shows that the fumigant regulations resulted in 6% fewer fumigations due to shifting applications outside May-October. Shifting applications outside May-October is a more effective reduction measure than switching to a low-VOC product because effectively no VOC emissions occur for the shifted applications. A year-round requirement would negate these reductions.
- Pesticide VOC emissions have little or no contribution to formation of particulate matter, the primary air pollutant outside May-October.
- DPR can revise the restrictions to year-round in the future if it becomes necessary. However, DPR cannot make the restrictions less stringent in the future due to the anti-backsliding provisions of the federal CAA.
- The restrictions would likely not comply with the Administrative Procedures Act because they would cause an unwarranted regulatory burden outside May-October.

Regulatory Issues and Options: Estimated Nonfumigant VOC Reductions

The amount of VOC reductions achieved from nonfumigant restrictions depend on four factors: the pesticide products (by A.I.) included, the EP thresholds selected, the crops included, and the exceptions included.

DPR must balance these four factors to achieve the needed VOC reductions for the SJV (Figure 6). The analysis of various nonfumigant restriction scenarios below is based on the worst-case year of 2006 where SJV emissions were 21.3 tons/day (Figure 2e).

DPR estimates that the 2008 fumigant regulations would have decreased 2006 fumigant emissions, hence also total emissions, by 2.5 tons/day had they been in place at that time

(Tables 2 and 3). Thus, total 2006 emissions would have been 21.3 – 2.5 = 18.8 tons/day. This yields a target for adequate VOC reduction from nonfumigants of 18.8 – 17.2 = 1.6 tons per day to avoid the current regulatory trigger for a fumigant emission limit. Emissions less than 17.2 tons/day are desirable to account for variations in pesticide use, cropping patterns, and changes in product use from year to year.

Table 11a – b shows estimated VOC reductions from nonfumigant restrictions by A.I., EP thresholds, crops, and exceptions based on 2006 data. Table 12a – b shows theoretical VOC emissions based on 2006 data resulting from the various restriction scenarios. The values in Tables 11 and 12 were calculated by assuming each application in 2006 that used a high-VOC product instead used a product with an EP at the defined EP threshold.

The pesticide products (by A.I.) and crops included in the restrictions are the major factors in determining the level of VOC reductions achieved.

Table 11b shows that the theoretical 2006 VOC reduction for the products containing the top A.I. (chlorpyrifos) would have been 1.86 tons/day, with a total reduction of 3.18 tons/day if all four A.I.s were included in the restrictions. This is a difference of 1.32 ton/day between the least restrictive and most restrictive scenarios. Those estimated reductions assume the higher EP thresholds are selected, all crops are included, and no exceptions to the restrictions. Similarly, the estimated VOC reduction for the top crop (almond) would have been 1.11 tons/day, with a total reduction of 3.18 if all crops were included, a difference of 2.07 tons/day between the least restrictive and most restrictive scenario. Those theoretical reductions also assume higher EP thresholds are selected, all four A.I.s are included, and no exceptions to the restrictions.

The product EP thresholds selected and the exceptions included are minor factors in determining the level of VOC reductions achieved.

VOC reductions for the higher EP thresholds would have been 3.18 tons/day (Table 11b), while a total VOC reduction of 3.62 tons/day would have been achieved if the lower EP thresholds were selected (Table 11a). This is a difference of 0.44 tons/day between the least restrictive and most restrictive scenarios. Both theoretical reductions assume all four A.I.s and all crops were included, and no exceptions to the restrictions.

The effect of allowing exceptions is relatively small. For the high EP threshold and all exceptions allowed, the theoretical reduction in emissions would have been 2.70 as compared to 3.18 (Table 11b). This is a difference of 0.48 tons/day between the least restrictive and most restrictive scenarios. The corresponding "exception allowed"/"no exception" comparison under a low EP threshold assumption yields VOC reduction estimates of 3.13 and 3.62 tons per day, respectively. The emissions associated with the exceptions were calculated as follows. Emissions were calculated directly from pesticide use reports for the structural, non-production agricultural, gibberellins less than 8 grams/acre (as recommended by UC), Section 18, and Section 24(c) applications because these specific applications can be identified. Emissions for chlorpyrifos applications to control aphids on cotton were assumed to be 10% of all chlorpyrifos emissions, based on a personal communication with UC staff. Emissions from quarantine or other USDA/CDFA programs were assumed to be negligible, 0.0001 tons/day because only one chlorpyrifos application has occurred for this use in the last 10 years. Precision sprayer applications were assumed to negate 1% of the VOC reductions.

DPR can consistently achieve the SIP reduction goal for the SJV with restrictions on high-VOC products. No restrictions are needed for low-VOC products.

The analysis shows that if all abamectin, chlorpyrifos, gibberellins, and oxyfluorfen applications in 2006 had used low-VOC products on all crops, total 2006 pesticide VOC emissions would have been 15.2-15.6 tons/day, depending on the EP thresholds selected and the exceptions included. This compares favorably with the trigger for a fumigant emissions limit of 17.2 tons/day previously discussed, and provides a margin in light of (a) uncertainty in the analysis and (b) the inherent variability in cropping patterns, pesticide use, and product use trends. The combined fumigant restrictions and nonfumigant restrictions combined would ensure that the SIP goal of 18.1 tons/day would be met each year, and the 17.2 tons/day trigger for a fumigant emissions limit would not be exceeded.

An emission level of less than 17.2 tons/day may be achieved with less stringent nonfumigant restrictions. DPR can lessen the agricultural impact of the nonfumigant restrictions by selecting the higher EP thresholds and including all exceptions, and still achieve the VOC reduction goals. The VOC reduction goals can also be achieved without restrictions on products containing all four A.I.s and/or all crops. Table 12b shows the various combinations of A.I.s and crops that will achieve the needed reductions.

Regulatory Issues and Options: Enforcing Nonfumigant VOC Restrictions

DPR has several options for enforcing restrictions on nonfumigant high-VOC products.

DPR has legal authority to regulate sales and use of pesticides using three methods: label changes, state regulations, or county permit conditions for restricted materials. Label changes are probably the easiest use restrictions to enforce, but they have several disadvantages in this case.

- Label changes are most feasible if year-round restrictions are needed statewide. For nonfumigant VOCs, restrictions are only needed in the SJV during May-October.

- Use restrictions may change from year to year, as described below. Labels that change from year to year would be difficult for compliance and enforcement due to carryover of older products.
- DPR has limited authority over labels. Only registrants and U.S. EPA can change label requirements. DPR approves labels, but does not have legal authority to require changes. Additionally, coordinating label revisions with registrants in a timely manner would be difficult.

Label changes are infeasible for most of the specific options discussed below.

Developing new regulations can achieve the nonfumigant VOC reductions and provide the flexibility that labels lack. The regulations could take the form of a registration requirement, sales restrictions, or use restrictions. A registration requirement is likely the preferred approach if the low-VOC products are required statewide, year-round, with few exceptions. Sales or use restrictions are likely the preferred approach if low-VOC products are only required in the SJV during May-October. However, the regulations would need some method to ensure compliance with sales or use restrictions. Several specific options for regulations are described below.

Restricted materials are potentially hazardous pesticides that require a permit issued by the CAC, after an evaluation of local conditions, and can only be applied by a certified applicator. None of the major nonfumigant VOC contributors are restricted materials, so permit conditions by CACs are not currently possible. Regulations would be needed to designate additional A.I.s as restricted materials, but this is normally a statewide action. More details on the restricted materials option are given below.

DPR can revise the trigger for fumigant emission limits with certain enforcement options.

Regulations on sales or use offer the opportunity to replace or amend the trigger for fumigant emission limits in current regulations. Fumigants account for approximately one-quarter of the pesticides emissions in the SJV, and nonfumigants account for three-quarters. Under the current regulations, a fumigant limit is triggered even if emissions exceed a specified level due to an increase in nonfumigant emissions. It’s possible that current regulations would require a major decrease or a total prohibition of fumigants, and still not achieve the pesticide SIP goal for the SJV due to increased nonfumigant emissions. Additional reasons that strict reliance on fumigant emissions reductions is undesirable for the SJV are complex cropping patterns and the large number of counties involved. In comparison, the fumigant limit and allowance program in the Ventura NAA is relatively easy to administer because the allowances are issued by a single county agricultural commissioner and the great majority of the allowances are issued for strawberries, with grower assistance provided by the California Strawberry Commission. A fumigant limit and allowance program in the SJV would be much more difficult to administer because DPR would need to coordinate the activities of eight CACs for multiple crops.

DPR could replace the SJV trigger for fumigant limits with a trigger for restrictions on nonfumigant high-VOC products (i.e. if pesticide emissions exceed 95% of the SIP goal, nonfumigant restrictions would be triggered in the SJV instead of fumigant allowances). Alternatively, DPR's Director could have discretion to trigger a fumigant limit or nonfumigant restrictions, depending on which pesticides increased. However, providing this discretion in regulations would be problematic because of the uncertain criteria DPR's director would use. Current regulations require DPR to evaluate the need for a fumigant limit each year. This annual evaluation will remain unchanged even if the fumigant limit is replaced with a trigger for nonfumigant restrictions. Specific options for enforcing nonfumigant restrictions are described below and summarized in Table13.

Option 1: Deny/cancel registrations for nonfumigant high-VOC products, with exceptions.

This could be a simple approach, if few exceptions are granted. This would likely require low-VOC products statewide, year-round, but reductions are only needed in SJV during May-October. Compliance should be good, if few exceptions are granted. High-VOC products would have labels with limited uses for crops-pests that are not controlled with low-VOC products. Compliance would be uncertain if numerous crops-pests can use high-VOC products, unless there is some new procedure to ensure that low-VOC products are used when required. This option would require low-VOC products statewide, year-round, unless the SJV during May-October is specified on the labels. Restrictions would still be in effect for years when additional VOC reductions are not needed to achieve the SIP goal. The fumigant limit trigger would remain unchanged.

Option 2: Prohibit use of certain nonfumigant high-VOC products in SJV during May-October, with exceptions.

This is probably the simplest of the use restrictions. The regulations would need to include a comprehensive list of exceptions to the high-VOC product restrictions. Disadvantages include a requirement for VOC reductions when they may not be needed. Extensive outreach would likely be needed to ensure compliance, at least for the first few years. The compliance methods described for Options 4a, 4b, and 4c could be used, but that would negate Option 2's advantage of simplicity. Restrictions would still be in effect for years when additional VOC reductions are not needed to achieve the SIP goal. The fumigant limit trigger would remain unchanged.

Option 3: Make additional A.I.s restricted materials.

CACs would evaluate the need for high-VOC products through the permitting process. This is most consistent with current regulatory structure. The fumigant limit trigger may or may not be replaced with this option. Compliance would be more certain through the permitting process. This option likely provides the most flexibility. It would be possible to have different permit conditions in different counties to minimize the impact and/or maximize VOC reductions. A key disadvantage is the need for some growers to obtain a restricted materials permit and become certified applicators for the first time. Certified applicators are unnecessary for VOC purposes because special equipment, procedures, or precautions are not needed. Workload would increase for CACs because an evaluation of local conditions is required for all restricted materials. The additional work would have little value because an evaluation of local conditions would not be needed for VOC purposes.

Option 4: Replace the fumigant limit trigger with a trigger for use restrictions on nonfumigant high-VOC products in the SJV during May-October, with exceptions.

This option removes the possibility of fumigant allowances and would implement new use restrictions only if the trigger level is exceeded and VOC reductions are needed to achieve the SIP goal. Restrictions on high-VOC products may be in effect for some years, but not others. The annual emission inventory report would be used to determine if the trigger level is exceeded. A key issue with this option is the method to ensure compliance. The following are compliance options.

Option 4a: To ensure compliance if the nonfumigant restrictions are triggered, growers would need to obtain an "authorization" for high-VOC products from the CAC. The regulations would specify the situations for which the CAC could issue an authorization. Applications that use low-VOC products would not need an authorization. The process to obtain the authorization would likely be similar to a restricted materials permit. DPR would provide a fact sheet that explains the regulations and lists the allowed uses for the high-VOC products. A key disadvantage for this option is the possibility that the CAC may need to administer a new program. However, this program may be preferable to the possibility of administering a fumigant allowance program or the additional workload of issuing a restricted materials permit. The possibility of requiring authorizations provides additional incentive for voluntary reductions. Additional outreach would be needed for growers who do not routinely interact with the CAC.

Option 4b: To ensure compliance if the nonfumigant restrictions are triggered, pesticide dealers would be required to provide information on the high-VOC prohibitions. For example, as a condition of sale, the regulations could require purchasers to read a form and self-certify that the high-VOC product will be used for an allowed exception. This sales requirement is similar to current dealer regulations for tributyltin and clopyralid, but the number of sales affected would be much greater. Alternatively, pesticide dealers could be required to provide a fact sheet explaining the nonfumigant restrictions to purchasers of high-VOC products. DPR should notify and provide information to pesticide dealers if the trigger level is exceeded. The sales requirement may need to apply to all dealers because the amount of pesticides purchased outside the SJV for use inside the SJV is unknown. There are approximately 1100 pesticide dealers in the SJV. Minimal outreach to growers would be needed because agricultural pesticides can only be purchased from licensed dealers.

Option 4c: To ensure compliance if the nonfumigant restrictions are triggered, purchase or use of high-VOC product would require a written recommendation from a licensed agricultural pest control adviser (PCA). A PCA recommendation is currently optional for all pesticides. This option would require a grower to obtain a PCA recommendation as a condition of purchase and/or use of the specified high-VOC products. Additional outreach will be needed for growers who do not routinely use a PCA.
Options 4a, 4b, and 4c can be implemented singly or in any combination.

DPR needs to consider other regulatory issues.

Only Option 1 (deny/cancel registrations) has a major role for registrants, but they are affected by the other options. Options 3 (restricted materials) and 4 (high-VOC restrictions trigger) could cause the nonfumigant restrictions to change from year to year. This may or may not place a burden on production. Any of the options will provide incentive for the registrants without a low-VOC product to reformulate. Registrants may not continue to produce and sell high-VOC products, even in areas outside of the SJV. Requiring product labels for the affected A.I.s to include a high-VOC/low-VOC designation may assist in compliance. However, only the registrants and U.S. EPA implement this action. DPR lacks legal authority to require label changes.

Options 3 (restricted materials) and 4 (high-VOC restrictions trigger) could cause the high-VOC restrictions to change from year to year. DPR would use its VOC annual report to implement these restrictions. There is an inherent lag in the restrictions by using the annual report. The VOC annual report and emission inventory rely on data from pesticide use reports. Under current policy, CACs electronically submit all pesticide use reports to DPR by August 1 for the previous year. DPR usually releases the draft annual report for public comment in November, and finalizes the report the following March or April. With this timeline, there will be a two-year lag in implementing restrictions under Options 3 or 4. For example, during the fall of 2013, DPR will determine if high-VOC restrictions are needed for May-October 2014, based on the pesticide use and VOC emissions for 2012. As discussed in the next section, it seems infeasible for CACs to submit pesticide use reports early enough to reduce the lag.

The current timing of the annual report may make Option 4b (high-VOC restrictions trigger with dealer requirements) problematic. The high-VOC restrictions would not be triggered until the annual report is finalized in March or April. This means that high-VOC products could be purchased without restrictions until that time. However, the restrictions on use of high-VOC products would still be in effect by May. People purchasing high-VOC products prior to the final report in March or April may be unaware of the use restrictions beginning in May.

Options 4b (high-VOC restrictions trigger with dealer requirements) and 4c (high-VOC restrictions with PCA requirements) can also be implemented independently from the use restrictions. For example, pesticide dealers could be required to provide nonfumigant VOC information even if the trigger level is not exceeded. This would result in more consistent actions by dealers and PCAs, alleviate some of the timing issues discussed above, and discourage use of high-VOC products even if the trigger is not exceeded.

Options 3 (restricted materials) and 4 (high-VOC restrictions trigger) should include criteria to drop the high-VOC restrictions once implemented, if emissions decrease sufficiently. However, the lag to compile pesticide use reports could make the timing problematic. The criteria to drop the high-VOC restrictions would be complex because DPR could not use actual VOC emission data. For the years when the high-VOC restrictions were in effect, DPR would need to estimate hypothetical emissions as if the restrictions were not in effect.

Options 3 (restricted materials) and 4 (high-VOC restrictions trigger) could cause the nonfumigant restrictions to change from year to year. This may or may not place a burden on production by registrants. There could also be “downstream” effects with pesticide dealers or growers possessing high-VOC products, but being unable to sell or use them.

Acrolein is the highest pesticide VOC contributor in the SJV (Table 5) that is not included in the fumigant regulations, and was not considered for nonfumigant restrictions. Acrolein (Magnacide®) is used as an aquatic herbicide primarily in irrigation canals. The products contain few if any inert ingredients, so they cannot be reformulated. Acrolein is applied by injection below the water surface, so changes to application methods seem infeasible. Acrolein would require a separate regulatory action if its VOC emissions need to be reduced.

As discussed above, the 2010 pesticide VOC emissions for the SJV were less than one ton/day of triggering a fumigant limit. Anecdotal evidence indicates that emissions in 2011 may be higher than 2010, possibly triggering a fumigant limit for 2013 in the SJV. Options 2, 3, and 4 involve use restrictions and would likely achieve VOC reductions faster than the registration actions of Option 1. Completing the rulemaking process for Options 2, 3, or 4 so nonfumigant use restrictions go into effect before May 2013 would avoid triggering a fumigant limit.

Other regulatory options seem infeasible.

The lag in pesticide use reporting likely makes a “track and regulate” system infeasible. A track and regulate system would involve real-time compilation of pesticide use data, and implementing restrictions if a certain target emission level is reached. Current regulations require most pesticide use reports to be submitted to the CAC by the 10th day of the month following the application (licensed pest control businesses must report within seven days of application). Unless reported electronically, it usually takes several weeks or months for CACs to enter pesticide use report information into the database. Pesticide use data could be obtained earlier under Option 3 (restricted materials) because restricted materials require notification (notice of intent) to the CAC prior to use. However, application plans may change and several notices of intent may be filed for a single application, or the application may never occur. Additionally, information on the notice of intent is not available electronically. The system would require tracking use for all eight SJV counties combined, with CACs sending use data to DPR on a real-time basis, and DPR converting the use data to VOC emissions on a real-time basis. Even if a near real-time reporting system could be developed, implementing restrictions if a trigger level is exceeded would be difficult and uncertain. Outreach to growers and applicators, and ensuring compliance would be difficult if use restrictions are triggered. Lastly, prohibition of high-VOC products may be insufficient to achieve the SIP goal if restrictions are triggered in September or October. A track and regulate system is infeasible without major changes to the pesticide use reporting system, and could trigger more severe restrictions than currently proposed.

"Episodic" restrictions may not achieve the SIP reduction goals. Episodic restrictions would be similar to no-burn days, where pesticide restrictions would only be in effect for days when ozone is expected to be high. In theory, this may reduce ozone concentrations, but compliance with the SIP goal is uncertain. DPR is legally required to reduce total pesticide VOC emissions by a specified amount during the May through October period, as calculated using the emission inventory methodology. VOC reductions that occur only on designated days may be insufficient to achieve the SIP goal. DPR is not required to reduce VOC emissions on each day, and it is not required to reduce ozone concentrations.

Estimated Effects, Risks, and Costs of Nonfumigant VOC Restrictions

Nonfumigant restrictions are needed to meet DPR's legal obligation to reduce pesticide VOC emissions, but the reduction in ozone levels will likely be minimal.

The SJV and other areas of California exceed the federal and state air quality standards for ozone several times each year. Reductions of both VOCs and nitrogen oxides are needed to reduce ozone concentrations, but ozone levels in rural areas such as the SJV primarily depend on nitrogen oxides. ARB's SIP discusses these issues in more detail <http://www.arb.ca.gov/planning/sip/2007sip/2007sip.htm>.

Pesticide products contribute approximately 6% of the total VOC emissions for SJV, and negligible emissions of nitrogen oxides. Therefore, restrictions on nonfumigant products will provide minimal overall reduction in VOC emissions and resulting ozone air concentrations. The restrictions should reduce VOC emissions by approximately 2 tons/day during a worst-case year, less than a 1% reduction in total VOC emissions from all sources in the SJV. However, even the largest sources contribute less than 15% to the total VOC emissions, and pesticide products are

consistently among the top ten VOC sources in the SJV. Reductions from many sources are needed to achieve the ozone air quality standard. Moreover, nonfumigant pesticides is one of the few, if only, significant VOC sources without VOC control measures. ARB's SIP discusses these issues in more detail <http://www.arb.ca.gov/planning/sip/2007sip/2007sip.htm>.
Different VOCs create different amounts of ozone. VOCs with higher reactivities create more ozone, all other factors being equal. DPR evaluated the reactivity of the major nonfumigants to determine the effectiveness of reducing their emissions. In general, high-VOC abamectin, chlorpyrifos, and oxyfluorfen products contain ingredients with higher reactivity and potentially create more ozone, compared to other major nonfumigants. Some but not all gibberellins products have lower reactivity. While product reactivity should be considered, DPR's current legal obligation is to reduce the mass of VOCs, regardless of reactivity. DPR's evaluation of reactivity of pesticide products discusses these issues in more detail <http://www.cdpr.ca.gov/docs/emon/vocs/vocproj/voc_research.htm>.

Nonfumigant VOC restrictions should have little or no impact on efforts to address other adverse environmental or health effects from pesticides.

As toxic chemicals, pesticides can cause other adverse environmental or health effects. Abamectin, gibberellins, and oxyfluorfen have few if any other environmental or health concerns at this time. DPR is evaluating and regulating chlorpyrifos for aquatic toxicity and human exposure concerns. These other concerns pertain only to chlorpyrifos as an A.I., not the inert ingredients in products. Therefore, any VOC restrictions for chlorpyrifos products will have little or no effect on the other mitigation efforts. DPR should craft the nonfumigant VOC restrictions so that they do not cause an increase in the amount of A.I. applied to offset lower efficacy of low-VOC products.

DPR and other agencies have programs to encourage the use of Integrated Pest Management and other techniques to reduce the use and risks of pesticides. The nonfumigant VOC restrictions should have no impact on DPR's pest management programs. USDA-EQIP provides matching funds to growers for precision pesticide sprayers, fumigant water treatments, and low-VOC pesticide products. These funds are normally available only for voluntary measures. It is uncertain what effect nonfumigant VOC restrictions will have on EQIP.

Most current abamectin, chlorpyrifos, gibberellins, and oxyfluorfen applications in the SJV use high-VOC products.

Table 14 and Appendix 2 show that most of the abamectin, chlorpyrifos, gibberellins, and oxyfluorfen applications used high-VOC products in the SJV for the most recent year reported (2010). Overall, 77% of the 2010 applications and 48% of the acreage used high-VOC products. High-VOC abamectin and oxyfluorfen products were used most frequently, approximately 90% of the applications and acreage. Chlorpyrifos was the one pesticide for which low-VOC products were used for the majority of the applications. High-VOC chlorpyrifos products were used for 44% of the applications and 12% of the acreage.

The costs of nonfumigant VOC restrictions are uncertain.

As part of the normal rulemaking process, ARB has conducted an economic analysis of the proposed regulations (Appendix 2). Most costs are due to some growers switching from high-VOC products to low-VOC products, and the higher cost of most of the low-VOC products. Under contract to CDFA, UC estimated the grower cost of various low-VOC products and alternatives (Appendix 1). The primary reason for the uncertain costs is because restrictions may only go into effect if an emissions trigger level is exceeded. There may be no restrictions and no additional costs if the trigger level is not exceeded. If the trigger level is exceeded, some of the applications that use high-VOC products would be required to switch to low-VOC products. If the high-VOC restrictions include exceptions, those applications would not be required to switch to low-VOC products. Table 14 shows that approximately 50% of the A.I. applied and 43% of the acreage treated with high-VOC products would be required to switch to low-VOC products, assuming the restrictions include products containing the top four A.I.s, all crops, and all exceptions. Detailed data for major crops is shown in Appendix 3.

Additional Research Needed for Nonfumigant VOC Restrictions

UC has evaluated the efficacy and cost of several low-VOC products for major crops such as almonds, cotton, and grapes. However, UC has not evaluated some of the pesticides that have recently started to have major VOC contributions, and most minor crops. This work should continue in the event that the nonfumigant restrictions implemented do not consistently achieve the required VOC reductions and more stringent requirements are needed.

Gibberellins registrants should attempt to develop liquid low-VOC products and/or repackage solid products to make low application rates easier to measure and more accurate.

Conclusions and Recommendations for Nonfumigant VOC Restrictions

We developed the regulatory options in consultation with numerous people within and outside DPR, including all affected branches within DPR; other agencies including staff from USDA, U.S. EPA, CDFA, ARB, the Office of Environmental Health Hazard Assessment, the Department of Toxic Substances Control, the State Water Resources Control Board, the California Department of Public Health, Cal/Recycle, the San Joaquin Valley's Air Pollution Control District, and CACs; extension specialists with the UC; and representatives from groups that will be directly affected by the restrictions including registrants, agricultural commodity organizations, PCAs, pesticide dealers, applicators, and growers. DPR invited several environmental and worker organizations to discuss the regulatory options, but all declined the invitation. We received comments at several public meetings with DPR's Pesticide Registration and Evaluation Committee, DPR's Agricultural Pest Control Advisory Committee, and DPR's Pest Management Advisory Committee. The following are our conclusions and recommendations based on these discussions and evaluation of the available VOC emission data.

DPR's nonfumigant restrictions should include one to four A.I.s in products formulated as emulsifiable concentrates.

Emulsifiable concentrates containing abamectin, chlorpyrifos, gibberellins, or oxyfluorfen are consistently among the highest nonfumigant VOC contributors in the SJV. Other nonfumigants are relatively high VOC contributors in some years, but not other years. Low-VOC products containing abamectin, chlorpyrifos, gibberellins, or oxyfluorfen are available and feasible for the majority of uses, but voluntary efforts to switch to the low-VOC products have had limited results. The needed VOC reductions for the SJV can be achieved with restrictions on chlorpyrifos, the largest nonfumigant VOC contributor. However, the agricultural impact may be lessened (or at least more certain) with less stringent restrictions on products for all four A.I.s. Restrictions on the A.I.s could also be phased in. For example, restrictions on chlorpyrifos products could go into effect immediately, and restrictions on products with the other A.I.s could go into effect in later years. This would give growers more time to adjust to the low-VOC products. However, phasing in the restrictions can make achieving the needed VOC reductions difficult depending on the number of crops included (see next conclusion).

DPR's nonfumigant restrictions can achieve the needed VOC reductions by including products with a greater number of A.I.s, higher EP thresholds, fewer crops, and all exceptions.

DPR will need to balance four factors to achieve the needed VOC reductions from the nonfumigant restrictions: the pesticide products (by A.I.) included, the EP thresholds selected, the crops included, and exceptions to the restrictions. DPR can achieve the needed reductions without restrictions on products for all four A.I.s under consideration or without restrictions on all crops. UC has evaluated the impact and cost of all four A.I.s for major crops, such as almonds, cotton, and grapes. The exceptions recommended for these crops are well documented. In contrast, the efficacy, cost, and other impacts from use of low-VOC products for minor crops are uncertain. Therefore, the nonfumigant VOC restrictions should include a greater number of A.I.s and fewer crops.

The EP thresholds have a smaller effect on nonfumigant VOC reductions compared to the pesticide products or crops included in the restrictions. The needed VOC reductions can still be achieved with the higher EP thresholds, and the market disruptions will be minimized because this will designate products from multiple registrants as low-VOC. DPR can make the EP

thresholds more stringent in the future if needed. Even if the most stringent EP thresholds are selected, several products for each A.I. will remain available. These nonfumigant VOC restrictions will not result in the prohibition of any A.I.s in the SJV or elsewhere.
The exclusions and exceptions to the nonfumigant restrictions also have a smaller effect on VOC reductions compared to the pesticide products (by A.I.) or crops included. Most if not all exclusions and exceptions discussed should be adopted because:

- emissions are relatively small,
- problems with enforcing restrictions on structural applications, and
- possible increases in the amount of A.I. applied.

Alternatively, the restrictions could include an expiration date or phase out schedule for some of the exceptions.

DPR should propose nonfumigant VOC restrictions that are more stringent than needed, but implement final restrictions that are less stringent while still achieving the needed reductions.

DPR should use an apparent inconsistent approach in determining how stringent to make the nonfumigant VOC restrictions. DPR should first propose the maximum restrictions to gather complete information on the possible cost and impact. After receiving information and comments on the proposed restrictions, DPR's final restrictions should implement the minimal VOC reductions needed. DPR can make the nonfumigant VOC restrictions more stringent in the future if needed. Once the restrictions are in effect, DPR cannot make them less stringent due to the anti-backsliding requirements of the CAA. However, DPR should consider nonfumigant VOC restrictions that achieve extra reductions in case they are needed to offset:
unanticipated exceptions to restrictions,

- growers switching to alternative A.I.s with higher EP products,
- incomplete compliance, and
- to provide a margin for pesticide use that exceeds the historical pattern.

DPR should implement the nonfumigant restrictions only if the trigger level is exceeded and enforce the restrictions with requirements for purchasing a high-VOC product and/or require a PCA recommendation prior to using a high-VOC product (Options 4b and/or 4c).

DPR should enforce the nonfumigant VOC restrictions with Option 4 (high-VOC restrictions trigger). The use restrictions should only pertain to the SJV during May-October because this is the area and time period when nonfumigant VOC reductions are needed, and the restrictions can be applied to other areas or time periods in the future if necessary. Similarly, imposing the

nonfumigant restrictions only if the trigger level is exceeded will achieve the needed reductions, but will not require VOC reductions when they are not needed. DPR should develop criteria to end the restrictions if use levels decrease sufficiently.
Option 4b (dealer requirements) and/or 4c (PCA requirements) are preferred because of the increased CAC workload and greater outreach needed for Option 4a (CAC authorizations). Compliance may be acceptable with either Option 4b or 4c, but DPR should propose both to gather information on the economic and other impacts of both options. For the final regulations, DPR may want to select one or both options. Outreach to affected growers and applicators is more comprehensive through dealers, but PCAs will be more knowledgeable in determining when a high-VOC product can and cannot be used.

DPR should implement the nonfumigant VOC restrictions as sales and/or use regulations no later than April 2013.

Sales and/or use regulations are the best option if the restrictions only apply to the SJV and are tied to a trigger. Registration requirements or label changes are feasible only if the restrictions apply statewide and are consistent from year to year. DPR should complete the rulemaking process so nonfumigant restrictions go into effect by April 2013, and avoid triggering a fumigant emission limit. This will require noticing the proposed regulations for public comment by April 2012. Since the regulations are part of the SIP, a public hearing is required, and would be held sometime between May and July 2012.

We may need to revise these options and recommendations once the public comments for the proposed regulations are received.

Table 1. Median EP for each formulation class and used as default values, based on TGA for several products in each class.

Formulation Code	Formulation Class	Median EP (%)
A0	Dust/powder	1.53
B0	Emulsifiable concentrate	39.15
C0	Flowable concentrate	4.80
E0	Granular/flake	3.70
G0	Microencapsulated	3.24
H0	Oil	3.47
J0	Pellet/tablet/cake/briquet	5.18
K0	Pressurized dust	100.00*
L0	Pressurized gas	100.00*
M0	Pressurized liquid/sprays/foggers	100.00*
N0	Soluble powder	1.15
O0	Solution/liquid (ready-to-use)	7.30
P0	Wettable powder	1.85
R0	Dry flowable	1.02
Q0 and S0	Suspension and liquid concentrate	5.71**
T0	Other (liquid)	6.91
U0	Other (dry)	2.05

* Default EP of all pressurized products defined as 100.

** Q0 and S0 formulation classes are combined due to (a) low number of Q0 products (n = 6) and (b) no significant difference in median TGA for these formulation classes (Wilcoxon rank sum test, p = 0.8).

Table 2. Comparison of fumigant emissions and use prior to and after implementation of fumigant VOC regulations (2006-2007 versus 2008-2009 May-October annual average).

Fumigant VOC Emissions and Use	SJV NAA	Southeast Desert NAA	Ventura NAA
2006-7 Fumigant Emissions (tons/day)	6.47	0.49	3.06
2008-9 Fumigant Emissions (tons/day)	3.35	0.092	1.30
2006-7 Fumigant Use (tons/day)	14.39	0.92	8.89
2008-9 Fumigant Use (tons/day)	11.93	0.47	6.53
2006-7 versus 2008-9 Relative Difference (percent)			
Decrease in VOC emissions	48	81	57*
Decrease in Amount Applied	17	49	26*
Decrease Due to Low-Emission Methods**	31	32	31
2006-7 versus 2008-9 Mass Difference (tons/day)			
Decrease in VOC emissions	3.12	0.40	1.75*
Decrease Due to Low-Emission Methods**	2.01	0.16	0.95

* Some of the decrease in use for Ventura was due to the fumigant limit and allowances required by the regulations.

** Some of the decrease may be due to changes in the procedure for determining the frequency each fumigation method is used.

Table 3. Comparison of fumigant use prior to and after implementation of fumigant VOC regulations (2006-2007 versus 2008-2009 annual average). Data is for all fumigants combined.

Time Period	Fumigant Use		
	SJV NAA	Southeast Desert NAA	Ventura NAA
May-Oct 2006-7	7,005,537 lbs	490,624 lbs	3,283,589 lbs
Jan-Dec 2006-7	16,225,657 lbs	1,029,983 lbs	3,538,332 lbs
May-Oct as fraction of 2006-7	43%	48%	93%
May-Oct 2008-9	5,805,199 lbs	317,963 lbs	2,453,000 lbs
Jan-Dec 2008-9	15,710,197 lbs	950,877 lbs	3,018,515 lbs
May-Oct as fraction of 2008-9	37%	33%	81%

Table 4. Examples of reformulated nonfumigant products with lower EPs.

A.I.	Lower VOC Product	EP (%)	Comparable Higher VOC Product	EP (%)
Abamectin	Agri-Mek SC	5.63	Agri-Mek 0.15 EC	55.10
Abamectin	Abba 0.15 ME	30.73	Abba 0.15 EC	62.60
Chlorpyrifos	Lorsban Advanced	18.45	Lorsban 4E	50.00
Chlorpyrifos	Drexel Chlorpyrifos 4E-AG	18.20	Drexel Chlorpyrifos 4E-AG	52.90
Diazinon	Diazinon AG 600 WBC	9.22	Diazinon AG 500	56.76
Esfenvalerate	Fenvastar Plus Insecticide	2.19	Fenvastar EcoCap	51.78
Lambda-Cyhalothrin	Warrior II with Zeon Technology	18.67	Warrior with Zeon Technology	29.06
Oxyfluorfen	Goaltender	8.28	Goal 2XL	62.30
Oxyfluorfen	Willowood OxyFlo 4 SC	6.76	Willowood OxyFlo 2 EC	60.00
Oxyfluorfen	Oxystar 4L	10.63	Oxystar 2E	73.09
Oxyfluorfen	Galigan Slapshot	3.84	Galigan 2E	66.15
Pendimethalin	Prowl H2O	3.00	Prowl 3.3 EC	42.35

Table 5. VOC emissions by product primary A.I. in the SJV NAA during May-October, 2008-2010 annual average.

Product Primary A.I.	Rank	VOC Emissions (tons/day)	Percent of Pesticide Emissions	Cumulative%
Chlorpyrifos	1	1.8127	12.2380	12.2380
1,3-Dichloropropene*	2	1.2798	8.6405	20.8785
Metam-sodium*	3	0.9932	6.7052	27.5837
Abamectin	4	0.8078	5.4537	33.0374
Oxyfluorfen	5	0.7782	5.2538	38.2913
Gibberellins	6	0.7042	4.7540	43.0453
Methyl bromide*	7	0.6620	4.4697	47.5151
Bifenthrin	8	0.6528	4.4074	51.9224
Dimethoate	9	0.5045	3.4063	55.3288
Glufosinate-ammonium	10	0.3778	2.5505	57.8793
Potassium N-methyldithiocarbamate*	11	0.3674	2.4806	60.3599
Fenpyroximate	12	0.3536	2.3871	62.7470
Acrolein	13	0.3180	2.1466	64.8937
Trifluralin	14	0.3053	2.0609	66.9546
Glyphosate, isopropylamine salt	15	0.2975	2.0087	68.9633
Permethrin	16	0.2201	1.4860	70.4493
Mineral Oil	17	0.2194	1.4815	71.9309
Chloropicrin*	18	0.1989	1.3432	73.2741
Petroleum Oil, Unclassified	19	0.1841	1.2431	74.5171
Hexythiazox	20	0.1834	1.2380	75.7552
All other pesticides		3.5911	24.2448	100.0000
TOTAL		14.8118		

* Fumigant pesticide

Table 6. Availability of products with lower VOC emissions for major VOC contributors in the SJV. DPR considered reformulation and nonfumigant restrictions for the A.I.s highlighted. Fumigants and acrolein were not considered for reformulation or nonfumigant restrictions because they contain little or no VOCs as inert ingredients. Glufosinate, glyphosate, and oils were not considered for reformulation or restrictions because the EPs for all products are less than 15%. "Rank" is the pesticide VOC emissions ranking for the SJV during May-October 2008-2010. "Liquid Products Available" indicates if there are high-VOC and/or low-VOC products currently registered. "Solid Products Available" indicates if solid products are currently registered. All solid products are considered low-VOC, but may not be effective in all cases.

Product Primary A.I.	Rank	Liquid Products Available	Solid Products Available
Chlorpyrifos	1	High- and Low-VOC	Low-VOC
1,3-Dichloropropene*	2	High-VOC only	None
Metam-sodium*	3	High-VOC only	None
Abamectin	4	High- and Low-VOC	Low-VOC
Oxyfluorfen	5	High- and Low-VOC	Low-VOC
Gibberellins	6	High-VOC only	Low-VOC
Methyl bromide*	7	High-VOC only	None
Bifenthrin	8	High- and Low-VOC**	Low-VOC
Dimethoate	9	High-VOC only	Low-VOC
Glufosinate-ammonium	10	Low-VOC only	None
Potassium N-methyldithiocarbamate*	11	High-VOC only	None
Fenpyroximate	12	High- and Low-VOC	None
Acrolein	13	High-VOC only	None
Trifluralin	14	High-VOC only	Low-VOC
Glyphosate, isopropylamine salt	15	Low-VOC only	None
Permethrin	16	High- and Low-VOC**	Low-VOC
Mineral Oil	17	Low-VOC only	None
Chloropicrin*	18	High-VOC only	None
Petroleum Oil, Unclassified	19	Low-VOC only	None
Hexythiazox	20	High-VOC only	Low-VOC

* Fumigant pesticide

** Low-VOC products may not be registered for all uses.

Table 7a. Approximate change in cost of switching to a low-VOC alternative, by percentage. Negative value indicates a cost savings by switching to an alternative product.

Pesticide	Alfalfa	Almonds	Citrus	Cotton	Grapes	Walnuts
Abamectin	Low use	0%	Low use	0%	0%	0%
Chlorpyrifos	<0.1%	33%	0%	0%	20%	9%
Dimethoate	40%	No use	104%	?	Low use	No use
Gibberellins	No use	No use	-2%	No use	0.6%	No use
Oxyfluorfen	No use	6%	6%	6%	6%	6%

Table 7b. Approximate change in cost of switching to a low-VOC alternative, by amount per acre. Negative value indicates a cost savings by switching to an alternative product.

Pesticide	Alfalfa	Almonds	Citrus	Cotton	Grapes	Walnuts
Abamectin	Low use	$0/ac	Low use	$0/ac	$0/ac	$0/ac
Chlorpyrifos	$0.02/ac	$10.77/ac	$0/ac	$0/ac	$6.58/ac	$4.10/ac
Dimethoate	$14/ac	No use	$38/ac	No data	Low use	No use
Gibberellins	No use	No use	-$1.40/ac	No use	$1.20/ac	No use
Oxyfluorfen	No use	$1.19/ac	$1.19/ac	$1.19/ac	$1.19/ac	$1.19/ac

Table 8a. Actively registered agricultural products containing **abamectin** as the primary A.I. Products are listed in order by EP. Products highlighted indicate liquid products with lower EPs and may be used to determine the EP threshold for designating low-VOC and high-VOC products. The product amount is amount applied in the SJV during May-October 2010.

Product Name	Registration Number	Registrant	Formulation	EP (%)	Product Amt (pounds)
Prescription Treatment Brand Advance Granular	499-370-AA	Whitmire Micro-Gen Research	Granular/Flake	3.70	184
Prescription Treatment Brand Ascend Fire Ant Bait	499-370-ZA	Whitmire Micro-Gen Research	Granular/Flake	3.70	0
Clinch Ant Bait	10965-50068-AA	California Dept. Of Food & Ag.	Granular/Flake	3.70	943
Prescription Treatment Brand Advance Granular	499-370-ZB	Whitmire Micro-Gen Research	Granular/Flake	3.70	24
Clinch Ant Bait	100-894-ZA	Syngenta Crop Protection, Inc.	Granular/Flake	3.70	184,535
Prescription Treatment Brand Advance 375A Select	499-370-ZC	Whitmire Micro-Gen Research	Granular/Flake	3.70	26
Optigard Fire Ant Bait	100-893-ZB	Syngenta Crop Protection, Inc.	Granular/Flake	3.70	0
Prescription Treatment Brand Avert Cockroach	499-467-AA	Whitmire Micro-Gen Research	Pellet/Tablet/Cake/Briquet	5.18	49
Raid Double Control Small Roach Baits	4822-472-ZC	S.C. Johnson & Son Inc.	Pellet/Tablet/Cake/Briquet	5.18	0
Enforcer Antmax Bait Stations	40849-75-AA	ZEP Commercial Sales & Service,	Pellet/Tablet/Cake/Briquet	5.18	0
Enforcer Roachmax Bait Stations	40849-76-AA	ZEP Commercial Sales & Service,	Pellet/Tablet/Cake/Briquet	5.18	0
Raid Max Double Control Large Roach Baits	4822-472-ZH	S.C. Johnson & Son Inc.	Pellet/Tablet/Cake/Briquet	5.18	0
Raid Max Double Control Ant Baits	4822-472-ZI	S.C. Johnson & Son Inc.	Pellet/Tablet/Cake/Briquet	5.18	0
Avicta 400FS	100-1211-AA	Syngenta Crop Protection, Inc.	Aqueous Concentrate	5.50	0
Prescription Treatment Brand Avert Dry Flowable	499-294-ZA	Whitmire Micro-Gen Research	Dust/Powder	5.55	0
Agri-Mek SC Miticide/Insecticide	100-1351-AA	Syngenta Crop Protection, Inc.	Aqueous Suspension	5.63	1
Timectin 0.15 EC T&O Insecticide/Miticide	84229-1-AA	Tide International USA, Inc.	Emulsifiable Concentrate	29.75	0
Master Label - Abba 0.15 ME Miticide/Insecticide	66222-191-ML	Makhteshim-Agan	Microencapsulated	30.73	0
Abba Ultra Miticide/Insecticide	66222-226-AA	Makhteshim-Agan	Emulsifiable Concentrate	34.18	0
Abamectin E-Ag 0.15 EC Insecticide	79676-58-AA	Etigra	Emulsifiable Concentrate	39.15*	1,227
Timectin 0.15 EC Ag Insecticide/Miticide	84229-2-AA	Tide International USA, Inc.	Emulsifiable Concentrate	39.15*	17,167
Agmectin 0.15 EC	84229-2-AA-72662	Oro Agri, Inc.	Emulsifiable Concentrate	39.15*	6,518
Solera Abamectin 0.15EC Ag Insecticide/Miticide	82542-11-AA-84237	Solera Ato, LLC	Emulsifiable Concentrate	39.15*	1,149
Nufarm Abamectin 0.15 EC Insecticide	228-658-AA	Nufarm Americas Inc.	Emulsifiable Concentrate	39.15*	0
Nufarm Abamectin Spc 0.15 EC Insecticide	228-657-AA	Nufarm Americas Inc.	Emulsifiable Concentrate	39.15*	0

Product Name	Registration Number	Registrant	Formulation	EP (%)	Product Amt (pounds)
Merlin	81943-29-AA	Phoenix Environmental Care LLC	Emulsifiable Concentrate	39.15*	0
Agmectin 0.15ED Insecticide/Miticide	84229-2-ZA	Tide International USA, Inc.	Emulsifiable Concentrate	39.15*	0
Greyhound Insecticide	69117-2-AA	Arborsystems	Solution/Liquid	55.10	0
Agri-Mek 0.15 EC Miticide/Insecticide	100-898-ZA	Syngenta Crop Protection, Inc.	Emulsifiable Concentrate	55.10	116,183
Avid 0.15EC Miticide/Insecticide	100-896-ZA	Syngenta Crop Protection, Inc.	Emulsifiable Concentrate	55.10	55
Epi-Mek 0.15 EC Miticide/Insecticide	100-1154-AA	Syngenta Crop Protection, Inc.	Emulsifiable Concentrate	55.10	221,777
Ardent 0.15 EC Miticide/Insecticide	100-896-ZB	Syngenta Crop Protection, Inc.	Emulsifiable Concentrate	55.10	0
Aracinate	74779-1-AA	Rainbow Treecare Scientific	Other (Liquid)	55.10	0
Abacus Agricultural Miticide/Insecticide	83100-4-AA-83979	Rotam North America, Inc.	Emulsifiable Concentrate	60.54	58,371
Lucid Ornamental Miticide/Insecticide	83100-5-AA-83979	Rotam North America, Inc.	Emulsifiable Concentrate	60.54	141
Minx Ornamental Miticide/Insecticide	1001-83-AA	Cleary Chemical Corp.	Emulsifiable Concentrate	60.54	0
Solera Abamectin Agricultural Miticide/Insecticide	83100-4-AA-82542	Source Dynamics, LLC	Emulsifiable Concentrate	60.54	3
Zoro Miticide/Insecticide	67760-71-AA	Cheminova, Inc.	Emulsifiable Concentrate	61.20	36,807
Temprano	67760-71-AA-400	Chemtura Corporation	Emulsifiable Concentrate	61.20	7,172
Abba 0.15 EC	66222-139-AA	Makhteshim-Agan	Emulsifiable Concentrate	62.62	54,844
Quali-Pro Abamectin 0.15 EC	73220-10-AA	Farmsaver.Com, LLC	Emulsifiable Concentrate	62.62	362
Quali-Pro Abamectin 0.15 EX Miticide/Insecticide	66222-210-AA	Makhteshim-Agan	Emulsifiable Concentrate	62.62	0
Vivid II	64014-10-AA	Florida Silvics Inc., DBA Tree	Solution/Liquid	71.77	0
Abamectin E-Pro 0.15 EC Insecticide	79676-57-AA	Etigra	Emulsifiable Concentrate	72.96	70
Reaper 0.15 EC	34704-923-AA	Loveland Products, Inc.	Emulsifiable Concentrate	73.33	94,294

* DPR is evaluating the EPs for these liquid products. They have been assigned default EP values on an interim basis.

Table 8b. Actively registered agricultural products containing **chlorpyrifos** as the primary A.I. Products are listed in order by EP. Products highlighted indicate liquid products with lower EPs and may be used to determine the EP threshold for designating low-VOC and high-VOC products. The product amount is amount applied in the SJV during May-October 2010.

Product Name	Registration Number	Registrant	Formulation	EP (%)	Product Amt (pounds)
Prescription Treatment Brand Duraguard ME	499-367-ZA	Whitmire Micro-Gen Research	Aqueous Concentrate	0.00	0
Durashield CS Controlled Release Premise	499-419-ZB	Whitmire Micro-Gen Research	Microencapsulated	0.00	144
Dursban W	62719-352-AA	Dow Agrosciences LLC	Wettable Powder	1.85	0
Pyrinex Chlorpyrifos Insecticide	11678-58-AA	Makhteshim Chemical Works Ltd.	Other (Dry)	2.05	0
Lorsban 50W In Water Soluble Packets	62719-221-ZA	Dow Agrosciences LLC	Wettable Powder	3.03	0
Lorsban 50-W	62719-221-AA-10163	Gowan Company	Wettable Powder	3.03	0
Nufos 15G	67760-14-AA	Cheminova, Inc.	Granular/Flake	3.70	420
Rainbow Fire Ant & Insect Killer	13283-14-ZA	Rainbow Technology Corporation	Granular/Flake	3.70	0
Andersons Golf Products Insecticide III	9198-167-AA	Andersons Lawn Fertilizer	Granular/Flake	3.70	600
Lorsban-75WG	62719-301-AA	Dow Agrosciences LLC	Granular/Flake	3.70	390
Lorsban 75WG	62719-301-AA-10163	Gowan Company	Granular/Flake	3.70	507
Lorsban 15G Smartbox	5481-525-AA	Amvac Chemical Corporation	Granular/Flake	3.70	1,200
Lorsban 15G Granular Insecticide	62719-34-ZA	Dow Agrosciences LLC	Granular/Flake	5.33	14,880
HM-0531	62719-34-AA-5905	Helena Chemical Company	Granular/Flake	5.33	523
Saurus	62719-34-ZA-5905	Helena Chemical Company	Granular/Flake	5.33	9,605
Dursban 50W In Water Soluble Packets	62719-72-ZA	Dow Agrosciences LLC	Wettable Powder	10.80	35
Drexel Chlorpyrifos 4E-Ag	19713-520-AA	Drexel Chemical Company	Emulsifiable Concentrate	18.20	0
Lorsban Advanced	62719-591-AA	Dow Agrosciences LLC	Aqueous Concentrate	18.45	728,372
Lock-On Insecticide	62719-79-ZA	Dow Agrosciences LLC	Emulsifiable Concentrate	20.90	127,051
Govern 4E Insecticide	62719-220-AA-55467	Tenkoz Inc.	Emulsifiable Concentrate	50.00	208,994
Warhawk	62719-220-AA-34704	Loveland Products, Inc.	Emulsifiable Concentrate	50.00	31,825
Whirlwind	62719-220-AA-5905	Helena Chemical Company	Emulsifiable Concentrate	50.00	25,538
Eraser	62719-220-AA-71058	Independent Agribusiness Prof	Emulsifiable Concentrate	50.00	218
Agrisolutions Yuma 4E Insecticide	62719-220-AA-1381	Winfield Solutions LLC	Emulsifiable Concentrate	50.00	1,272
Hatchet	62719-220-ZC	Dow Agrosciences LLC	Emulsifiable Concentrate	50.00	344
Lorsban-4E	62719-220-ZA	Dow Agrosciences LLC	Emulsifiable Concentrate	51.32	83,929
Nufos 4E	67760-28-AA	Cheminova, Inc.	Emulsifiable Concentrate	52.30	240,390

Product Name	Registration Number	Registrant	Formulation	EP (%)	Product Amt (pounds)
Chlorpyrifos 4E Ag	66222-19-AA	Makhteshim-Agan	Emulsifiable Concentrate	52.90	17,302
Quali-Pro Chlorpyrifos 4E	66222-19-AA-73220	Farmsaver.Com, LLC	Emulsifiable Concentrate	52.90	47
Quali-Pro Chlorpyrifos 4E	66222-19-ZA	Makhteshim-Agan	Emulsifiable Concentrate	52.90	0
Warhawk	34704-857-AA	Loveland Products, Inc.	Aqueous Concentrate	54.41	170,147
Cobalt	62719-575-AA	Dow Agrosciences LLC	Emulsifiable Concentrate	68.61	22,717

Table 8c. Actively registered agricultural products containing **gibberellins** as the primary A.I. Products are listed in order by EP. The product amount is amount applied in the SJV during May-October 2010.

Product Name	Registration Number	Registrant	Formulation	EP (%)	Product Amt (pounds)
Gibgro 20% Powder	55146-53-ZA	Nufarm Americas Inc.	Dust/Powder	0.00	711
Gibgro 5% Powder	55146-56-ZA	Nufarm Americas Inc.	Dust/Powder	0.01	121
Pro-Gibb Plus 2x Plant Growth Regulator	73049-16-AA	Valent Biosciences Corporation	Soluble Powder	1.15	5,505
Release Plant Growth Regulator Soluble Powder	73049-6-AA	Valent Biosciences Corporation	Soluble Powder	1.15	0
GA3 20%	72639-13-AA	LT Biosyn, Inc.	Soluble Powder	1.15	852
N-Large 40 SP	57538-22-AA	Stoller Enterprises, Inc.	Soluble Powder	1.15	0
Falgro 20SP	62097-3-AA-82917	Fine Americas, Inc.	Soluble Powder	1.15	445
Progibb 40% Water Soluble Granules	73049-1-AA	Valent Biosciences Corporation	Granular/Flake	3.70	12,045
Provide 10 SG Plant Growth Regulator	73049-409-AA	Valent Biosciences Corporation	Granular/Flake	3.70	0
Progibb 40% Plant Growth Regulator	73049-1-ZA	Valent Biosciences Corporation	Granular/Flake	3.70	0
Fresco	62097-6-ZA-82917	Fine Americas, Inc.	Aqueous Concentrate	5.71*	0
Procone Plant Growth Regulator Solution	73049-32-AA	Valent Biosciences Corporation	Solution/Liquid	7.30*	0
N-Large Premier	57538-20-AA	Stoller Enterprises, Inc.	Aqueous Concentrate	79.02	974
GA3 4%	72639-8-AA	LT Biosyn, Inc.	Aqueous Concentrate	92.36	2,412
Gibbmax	69766-1-AA	Advanced Foliar Nutrients Systems	Other (Liquid)	92.43	20
Falgro 4L	62097-2-AA-82917	Fine Americas, Inc.	Solution/Liquid	93.82	28,114
Florgib 4L	62097-10-AA-82917	Fine Americas, Inc.	Aqueous Concentrate	93.82	0
Pro-Gibb 4% Plant Growth Regulator Solution	73049-15-AA	Valent Biosciences Corporation	Aqueous Concentrate	94.13	96,661
Progibb T & O Plant Growth Regulator	73049-15-ZA	Valent Biosciences Corporation	Aqueous Concentrate	94.13	24
Gibgro 4LS	55146-62-ZA	Nufarm Americas Inc.	Flowable Concentrate	94.87	61,740
Novagib 10L	62097-7-AA-82917	Fine Americas, Inc.	Aqueous Concentrate	98.91	0

* DPR is evaluating the EPs for these liquid products. They have been assigned default EP values on an interim basis.

Table 8d. Actively registered agricultural products containing **oxyfluorfen** as the primary A.I. Products are listed in order by EP. Products highlighted indicate liquid products with lower EPs and may be used to determine the EP threshold for designating low-VOC and high-VOC products. The product amount is amount applied in the SJV during May-October 2010.

Product Name	Registration Number	Registrant	Formulation	EP (%)	Product Amt (pounds)
Regal 0-0 Herbicide	48234-10-AA	Regal Chemical Company	Granular/Flake	3.70	0
Double O E-Pro Herbicide	79676-20-AA	Etigra	Granular/Flake	3.70	5,400
Permaguard	79676-20-AA-72112	Prokoz, Inc.	Granular/Flake	3.70	2,207
Two Ox E-Pro Herbicide	79676-38-AA	Etigra	Granular/Flake	3.70	0
Nufarm Double O SPC Herbicide	228-632-AA	Nufarm Americas Inc.	Granular/Flake	3.70	0
Galigan Slapshot	66222-107-ZA	Makhteshim-Agan	Aqueous Concentrate	3.84	2,771
Galigan H2O	66222-140-AA	Makhteshim-Agan	Aqueous Concentrate	5.71	427
Willowood Oxyflo 4 SC	87290-10-AA	Willowood, LLC	Aqueous Concentrate	6.76	0
Ortho Groundclear Superedger Plus Ready To Use	239-2516-ZD	Scotts Company	Solution/Liquid	7.30	0
Goaltender	62719-447-ZA	Dow Agrosciences LLC	Flowable Concentrate	8.28	16,330
Rout Ornamental Herbicide	58185-27-AA	Scotts-Sierra Crop Prot. Co.	Granular/Flake	8.60	1,465
Progrow Ornamental Herbicide 2	538-172-AA	Scotts Company	Granular/Flake	9.17	4,687
OH 2	538-172-ZA	Scotts Company	Granular/Flake	9.17	1,745
Pindar GT	62719-611-AA	Dow Agrosciences LLC	Aqueous Suspension	10.60	1,792
Oxystar 4L	42750-199-AA	Albaugh, Inc.	Emulsifiable Concentrate	10.63	0
Willowood Oxyflo 2 EC	87290-8-AA	Willowood, LLC	Emulsifiable Concentrate	60.00	21
Goal 2XL	62719-424-AA	Dow Agrosciences LLC	Emulsifiable Concentrate	62.30	315,487
Oxen Herbicide	34704-877-AA	Loveland Products, Inc.	Other (Liquid)	64.00	0
Galigan 2E Oxyfluorfen Herbicide	66222-28-AA	Makhteshim-Agan	Emulsifiable Concentrate	66.15	32,097
Oxystar 2E	42750-136-AA	Albaugh, Inc.	Emulsifiable Concentrate	73.09	18,411

Table 9. VOC emissions from abamectin, chlorpyrifos, gibberellins, and oxyfluorfen used for production agriculture, nonproduction agriculture, and structures in the SJV during May-October, annual average for 2008-2010.

Use Type	**VOC Emissions (pounds)**					**% of Total**
	Abamectin	**Chlorpyrifos**	**Gibberellins**	**Oxyfluorfen**	**Sum**	
Production agriculture	301,490	662,991	268,331	266,721	1,499,533	98.68
Nonproduction agriculture	318	449	668	18,250	19,685	1.30
Structural	133	48	0	130	311	0.02
Total	301,941	663,488	268,999	285,101	1,519,529	100.00

Table 10. VOC emissions from abamectin, chlorpyrifos, gibberellins, and oxyfluorfen products by crop or site in the SJV during May-October, annual average for 2008-2010.

Crop/Site	VOC Emissions (pounds)					% of Total	Cumulative %
	Abamectin	Chlorpyrifos	Gibberellins	Oxyfluorfen	Sum		
Almond	165,059	184,506	0	150,065	499,630	32.88	32.88
Citrus	25,134	143,533	108,929	1,102	278,697	18.34	51.22
Grapes	38,954	25,227	146,131	22,767	233,079	15.34	66.56
Cotton	27,363	83,727	0	17,742	128,832	8.48	75.04
Walnut	14,267	75,484	0	18,249	108,000	7.11	82.15
Alfalfa	3,058	104,264	0	5	107,327	7.06	89.21
Pistachio	19	0	0	37,951	37,971	2.50	91.71
Corn	26	36,767	0	26	36,819	2.42	94.13
Cherry	2,033	94	13,315	4,285	19,727	1.30	95.43
Rights of way	77	12	0	17,190	17,279	1.14	96.57
Cantaloupe	4,475	0	0	15	4,489	0.30	96.86
Plum	2,321	8	26	1,522	3,877	0.26	97.12
Watermelons	3,065	0	0	0	3,065	0.20	97.32
Peach	1,275	32	66	1,617	2,990	0.20	97.52
Beans, dried-type	2,449	386	0	35	2,870	0.19	97.70
Lettuce, head	2,548	0	0	0	2,548	0.17	97.87
Asparagus	0	2,151	0	0	2,151	0.14	98.01
Tomatoes	2,020	5	0	32	2,057	0.14	98.15
Nursery-outdoor	529	81	14	1,396	2,020	0.13	98.28
Nectarine	450	10	113	1,180	1,752	0.12	98.40
All other crops	6,821	7,201	405	9,922	24,349	1.60	100.00
Total (pounds)	301,941	663,488	268,999	285,101	1,519,529		
Total (tons/day)	0.82	1.80	0.73	0.77	4.13		

Table 11a. Estimated VOC reductions for various nonfumigant restrictions (negative values) and exceptions (positive values) in the SJV during May-October 2006, the highest year. *The EP* threshold (thd) *are set at the **lowest** level to achieve the greatest reductions.* Setting higher EP thresholds for abamectin and gibberellins could result in fewer market disruptions.

Scenario	Estimated VOC Reductions (tons/day) with Nonfumigant Restrictions				
	Abamectin EP thd=10%	Chlorpyrifos EP thd=25%	Gibberellins EP thd=5%	Oxyfluorfen EP thd=15%	Sum
Estimated reduction					
Alfalfa restrictions	-0.0069	-0.0978	0.0000	0.0000	-0.1048
Almond restrictions	-0.2490	-0.7342	0.0000	-0.2763	-1.2595
Cherry restrictions	0.0000	-0.0007	-0.0220	-0.0145	-0.0373
Citrus restrictions	-0.0236	-0.3473	-0.2950	-0.0061	-0.6720
Corn restrictions	0.0000	-0.0397	0.0000	0.0000	-0.0397
Cotton restrictions	-0.1089	-0.3897	0.0000	-0.0558	-0.5544
Grape restrictions	-0.0365	-0.0469	-0.3955	-0.0433	-0.5223
Pistachio restrictions	0.0000	0.0000	0.0000	-0.0401	-0.0401
Right of way restrictions	0.0000	0.0000	0.0000	-0.0498	-0.0499
Walnut restrictions	-0.0157	-0.1566	0.0000	-0.0480	-0.2203
Remaining crops restrictions	-0.0350	-0.0433	-0.0036	-0.0360	-0.1179
Sum of all crops/sites	-0.4756	-1.8563	-0.7162	-0.5700	-3.6181
Estimated exceptions					
Structural	0.0001	0.0002	0.0000	0.0000	0.0003
Non-production ag	0.0002	0.0003	0.0000	0.0204	0.0210
Chlorpyrifos cotton aphids	0.0000	0.0390	0.0000	0.0000	0.0390
Gibberellins <8 grams/acre	0.0000	0.0000	0.0674	0.0000	0.0674
Section 18*	0.0131	0.0000	0.0000	0.0000	0.0131
Section 24c*	0.0068	0.0744	0.0072	0.2185	0.3069
USDA/CDFA	0.0000	0.0001	0.0000	0.0000	0.0001
Precision sprayer	0.0048	0.0186	0.0072	0.0057	0.0362
Sum of all exceptions	0.0249	0.1326	0.0818	0.2446	0.4839
Reduction from all crops with all exceptions	-0.4507	-1.7237	-0.6344	-0.3255	-3.1342
Actual emissions	0.6000	3.9692	0.7607	0.7784	6.1082

* Section 18 for abamectin on lima beans.

** Section 24c for abamectin on alfalfa; chlorpyrifos on citrus; gibberellins on azaleas and tangerines; oxyfluorfen on peas, roses, clover, stone fruit, olives, and almonds.

Table 11b. Estimated VOC reductions for various nonfumigant restrictions (negative values) and exceptions (positive values) in the SJV during May-October 2006, the highest year. *The EP* thresholds (thds) *are set at the* ***highest*** *level to achieve the least reductions.* Greater reduction could be achieved by setting lower EP thresholds for abamectin and gibberellins, but that could cause market disruptions.

Scenario	Estimated VOC Reductions (tons/day) with Nonfumigant Restrictions				
	Abamectin EP thd=35%	**Chlorpyrifos EP thd=25%**	**Gibberellins EP thd=25%**	**Oxyfluorfen EP thd=15%**	**Sum**
Estimated reductions					
Alfalfa restrictions	-0.0031	-0.0978	0.0000	0.0000	-0.1009
Almond restrictions	-0.1037	-0.7342	0.0000	-0.2763	-1.1142
Cherry restrictions	0.0000	-0.0007	-0.0171	-0.0145	-0.0323
Citrus restrictions	-0.0098	-0.3473	-0.2281	-0.0061	-0.5914
Corn restrictions	0.0000	-0.0397	0.0000	0.0000	-0.0397
Cotton restrictions	-0.0456	-0.3897	0.0000	-0.0558	-0.4911
Grape restrictions	-0.0150	-0.0469	-0.3064	-0.0433	-0.4116
Pistachio restrictions	0.0000	0.0000	0.0000	-0.0401	-0.0401
Right of way restrictions	0.0000	0.0000	0.0000	-0.0498	-0.0499
Walnut restrictions	-0.0055	-0.1566	0.0000	-0.0480	-0.2101
Remaining crops restrictions	-0.0149	-0.0433	-0.0030	-0.0360	-0.0972
Sum of all crops/sites	-0.1975	-1.8563	-0.5546	-0.5700	-3.1785
Estimated exceptions					
Structural	0.0001	0.0002	0.0000	0.0000	0.0003
Nonproduction ag	0.0002	0.0003	0.0000	0.0204	0.0210
Chlorpyrifos cotton aphids	0.0000	0.0390	0.0000	0.0000	0.0390
Gibberellins <8 grams/acre	0.0000	0.0000	0.0674	0.0000	0.0674
Section 18*	0.0131	0.0000	0.0000	0.0000	0.0131
Section 24c**	0.0068	0.0744	0.0072	0.2185	0.3069
USDA/CDFA	0.0000	0.0001	0.0000	0.0000	0.0001
Precision sprayer	0.0020	0.0186	0.0055	0.0057	0.0318
Sum of all exceptions	0.0222	0.1326	0.0802	0.2446	0.4795
Reduction from all crops with all exceptions	-0.1754	-1.7237	-0.4744	-0.3255	-2.6990
Actual emissions	0.6000	3.9692	0.7607	0.7784	6.1082

* Section 18 for abamectin on lima beans.

** Section 24c for abamectin on alfalfa; chlorpyrifos on citrus; gibberellins on azaleas and tangerines; oxyfluorfen on peas, roses, clover, stone fruit, olives, and almonds.

Table 12a. Estimated VOC emissions with various nonfumigant A.I. and crop restrictions. *All scenarios assume that the EP* threshold*s for abamectin and gibberellins products are set at the* ***lowest*** *level of 10% and 5%, respectively.* All scenarios assume that the fumigant regulations reduce fumigant VOC emissions by 37%. Lower emission levels are achieved by restricting more nonfumigant A.I.s and/or more crops. Emissions are estimated for the SJV during May-October 2006, the highest year. Actual emissions for 2006 were 21.3 tons/day. The emission level goal for these nonfumigant restrictions combined with the fumigant regulations is 17.2 tons/day (trigger for fumigant limit) or less. Highlighted values indicate scenarios that achieve the emission level goal.

Scenario	**Estimated VOC Emissions (tons/day) with Lowest EPs, Fumigant Regs, and Nonfumigant Restrictions**			
	Top A.I. (Chlorpyrifos)	**Top 2 A.I.s (Previous+ Oxyfluorfen)**	**Top 3 A.I.s (Previous+ Gibberellins)**	**Top 4 A.I.s (Previous+ Abamectin)**
Estimated emissions with nonfumigant restrictions and no exceptions				
Top crop (almond)	18.052	17.776	17.776	17.527
Top 2 crops (previous+citrus)	17.705	17.422	17.127	16.855
Top 3 crops (previous+cotton)	17.315	16.977	16.682	16.300
Top 4 crops (previous+grape)	17.268	16.886	16.196	15.778
Top 5 crops (previous+walnut)	17.111	16.682	15.991	15.558
Top 6 crops (previous+alfalfa)	17.013	16.584	15.893	15.453
Top 7 crops (previous+right of way)	17.013	16.534	15.844	15.403
Top 8 crops (previous+pistachio)	17.013	16.494	15.803	15.363
Top 9 crops (previous+corn)	16.974	16.454	15.764	15.323
Top 10 crops (previous+cherry)	16.973	16.439	15.726	15.286
All crops	16.930	16.360	15.644	15.168
Estimated emissions with nonfumigant restrictions and all exceptions*				
Top crop (almond)	18.1845	18.0201	17.8573	17.5515
Top 2 crops (previous+citrus)	17.8372	17.6667	17.2089	16.8794
Top 3 crops (previous+cotton)	17.4474	17.2212	16.7634	16.3250
Top 4 crops (previous+grape)	17.4005	17.1309	16.2776	15.8027
Top 5 crops (previous+walnut)	17.2439	16.9263	16.0730	15.5825
Top 6 crops (previous+alfalfa)	17.1461	16.8285	15.9752	15.4777
Top 7 crops (previous+right of way)	17.1461	16.7786	15.9253	15.4278
Top 8 crops (previous+pistachio)	17.1461	16.7385	15.8852	15.3877
Top 9 crops (previous+corn)	17.1064	16.6988	15.8455	15.3480
Top 10 crops (previous+cherry)	17.1057	16.6836	15.8082	15.3107
All crops	17.0623	16.6043	15.7253	15.1928

* Possible exceptions to nonfumigant restrictions include the following uses: chlorpyrifos for cotton aphid, gibberellins <8 grams/acre, Section 18, Section 24c, USDA/CDFA projects, and smart sprayers.

Table 12b. Estimated VOC emissions with various nonfumigant A.I. and crop restrictions. *All scenarios assume that the EP thresholds for abamectin and gibberellins products are set at the* ***highest*** *level of 35% and 25%, respectively.* All scenarios assume that the fumigant regulations reduce fumigant VOC emissions by 37%. Lower emission levels are achieved by restricting more nonfumigant A.I.s and/or more crops. Emissions are estimated for the SJV during May-October 2006, the highest year. Actual emissions for 2006 were 21.3 tons/day. The emission level goal for these nonfumigant restrictions combined with the fumigant regulations is 17.2 tons/day (trigger for fumigant limit) or less. Highlighted values indicate scenarios that achieve the emission level goal.

Scenario	Estimated VOC Emissions (tons/day) with Highest EPs, Fumigant Regs, and Nonfumigant Restrictions			
	Top A.I. (Chlorpyrifos)	Top 2 A.I.s (Previous+ Oxyfluorfen)	Top 3 A.I.s (Previous+ Gibberellins)	Top 4 A.I.s (Previous+ Abamectin)
Estimated emissions with nonfumigant restrictions and no exceptions				
Top crop (almond)	18.052	17.776	17.776	17.672
Top 2 crops (previous+citrus)	17.705	17.422	17.194	17.080
Top 3 crops (previous+cotton)	17.315	16.977	16.748	16.589
Top 4 crops (previous+grape)	17.268	16.886	16.352	16.178
Top 5 crops (previous+walnut)	17.111	16.682	16.147	15.968
Top 6 crops (previous+alfalfa)	17.013	16.584	16.049	15.867
Top 7 crops (previous+right of way)	17.013	16.534	16.000	15.817
Top 8 crops (previous+pistachio)	17.013	16.494	15.959	15.777
Top 9 crops (previous+corn)	16.974	16.454	15.920	15.737
Top 10 crops (previous+cherry)	16.973	16.439	15.887	15.705
All crops	16.930	16.360	15.805	15.608
Estimated emissions with nonfumigant restrictions and all exceptions*				
Top crop (almond)	18.1845	18.0201	17.8557	17.6940
Top 2 crops (previous+citrus)	17.8372	17.6667	17.2742	17.1026
Top 3 crops (previous+cotton)	17.4474	17.2212	16.8287	16.6115
Top 4 crops (previous+grape)	17.4005	17.1309	16.4320	16.2000
Top 5 crops (previous+walnut)	17.2439	16.9263	16.2274	15.9899
Top 6 crops (previous+alfalfa)	17.1461	16.8285	16.1296	15.8890
Top 7 crops (previous+right of way)	17.1461	16.7786	16.0797	15.8391
Top 8 crops (previous+pistachio)	17.1461	16.7385	16.0396	15.7990
Top 9 crops (previous+corn)	17.1064	16.6988	15.9999	15.7593
Top 10 crops (previous+cherry)	17.1057	16.6836	15.9676	15.7270
All crops	17.0623	16.6043	15.8852	15.6297

* Possible exceptions to nonfumigant restrictions include the following uses: chlorpyrifos for cotton aphid, gibberellins <8 grams/acre, Section 18, Section 24c, USDA/CDFA projects, and smart sprayers.

Table 13. Overview of enforcement options for nonfumigant restrictions. All options include sales and/or use restrictions on certain high-VOC products in the SJV during May-October. Some options are more stringent, causing a greater burden. The recommended options are highlighted.

Option	Statewide/all year or SJV/May-Oct	VOC reduction achieved	Fumigant limit trigger	Compliance and enforceability	Extra impact*
1-Cancel high-VOC product registrations, with exceptions	Statewide, all year	Likely more than required	Unchanged	High, if few exceptions	Growers
2-Prohibit use of high-VOC products, with exceptions	Statewide or SJV, all year or May-Oct	Likely more than required	Unchanged	High, if extensive outreach	Growers
3-Designate additional restricted materials	SJV, May-Oct	Required reduction	Replaced??	High	Ag commissioners, some growers
4a-If triggered, high-VOC use restrictions; plus use "authorizations"	SJV, May-Oct	Required reduction	Replaced	High, if outreach	Possibly ag commissioners, growers
4b-If triggered, high-VOC use restrictions; plus dealer requirements	SJV, May-Oct	Required reduction	Replaced	High	Possibly dealers
4c-If triggered, high-VOC use restrictions; plus PCA recommendation	SJV, May-Oct	Required reduction	Replaced	High, if outreach	Possibly some growers

* Growers and applicators are impacted under all of the options because most applications will be required to use low-VOC products. The extra impact indicated reflects the relative workload and problems of making this change.

Table 14. Estimated applications that would be affected by nonfumigant high-VOC restrictions. Estimates are based on applications for all crops in the SJV during the most recent reported year (May-October, 2010). These estimates assume that the EP thresholds for abamectin and gibberellins products are set at the highest level of 35% and 25%, respectively. The estimates for the applications affected with the lowest EP thresholds would likely be the same or very similar. Only the exceptions for chlorpyrifos on cotton for aphids, gibberellins applied at <8 grams/acre, and Section 24c applications are included. The remaining exceptions are difficult to quantify and likely have few applications.

Application Parameters	Abamectin	Chlorpyrifos	Gibberellins	Oxyfluorfen	Sum
Total applications					
Number of applications	20,315	10,420	10,390	9,593	50,178
Area treated (acres)	1,662,438	2,560,976	382,989	444,103	5,050,506
A.I. (pounds)	13,685	766,524	16,160	100,073	896,442
Applications that used high-VOC products					
Number of applications	17,961	4,601	8,110	8,673	39,345
Area treated (acres)	1,460,409	315,564	267,820	402,002	2,445,795
A.I. (pounds)	13,663	397,583	10,250	90,589	512,085
Applications that used low-VOC products					
Number of applications	2,354	5,819	2,280	920	11,373
Area treated (acres)	202,029	2,245,412	115,169	42,102	2,604,712
A.I. (pounds)	22	368,941	5,910	9,484	384,357
Applications that used high-VOC products for an exception					
Number of applications	105	522	3,306	1,448	5,381
Area treated (acres)	8,220	43,959	125,795	73,286	251,260
A.I. (pounds)	91	44,278	1,229	14,372	59,970
High-VOC applications that would switch to low-VOC due to restrictions (exceptions do not switch)					
Number of applications	17,856	4,079	4,804	7,225	33,964
Area treated (acres)	1,452,189	271,605	142,026	328,716	2,194,536
A.I. (pounds)	13,572	353,306	9,021	76,217	452,116
Percent that used high-VOC products					
% of applications	88.41	44.16	78.06	90.41	77.58
% of area treated (acres)	87.85	12.32	69.93	90.52	48.43
% of A.I. (lbs)	99.84	51.87	63.43	90.52	57.12
Percent that used low-VOC products					
% of applications	11.59	55.84	21.94	9.59	22.42
% of area treated (acres)	12.15	87.68	30.07	9.48	51.57
% of A.I. (lbs)	0.16	48.13	36.57	9.48	42.88

Percent that would switch to low-VOC products due to restrictions (exceptions do not switch)					
Percent of applications	87.90	39.15	46.24	75.32	66.97
Percent of area treated (acres)	87.35	10.61	37.08	74.02	43.45
Percent of A.I. (lbs)	99.17	46.09	55.82	76.16	50.43

Figure 1. Ozone nonattainment areas included in the pesticide element of the SIP.

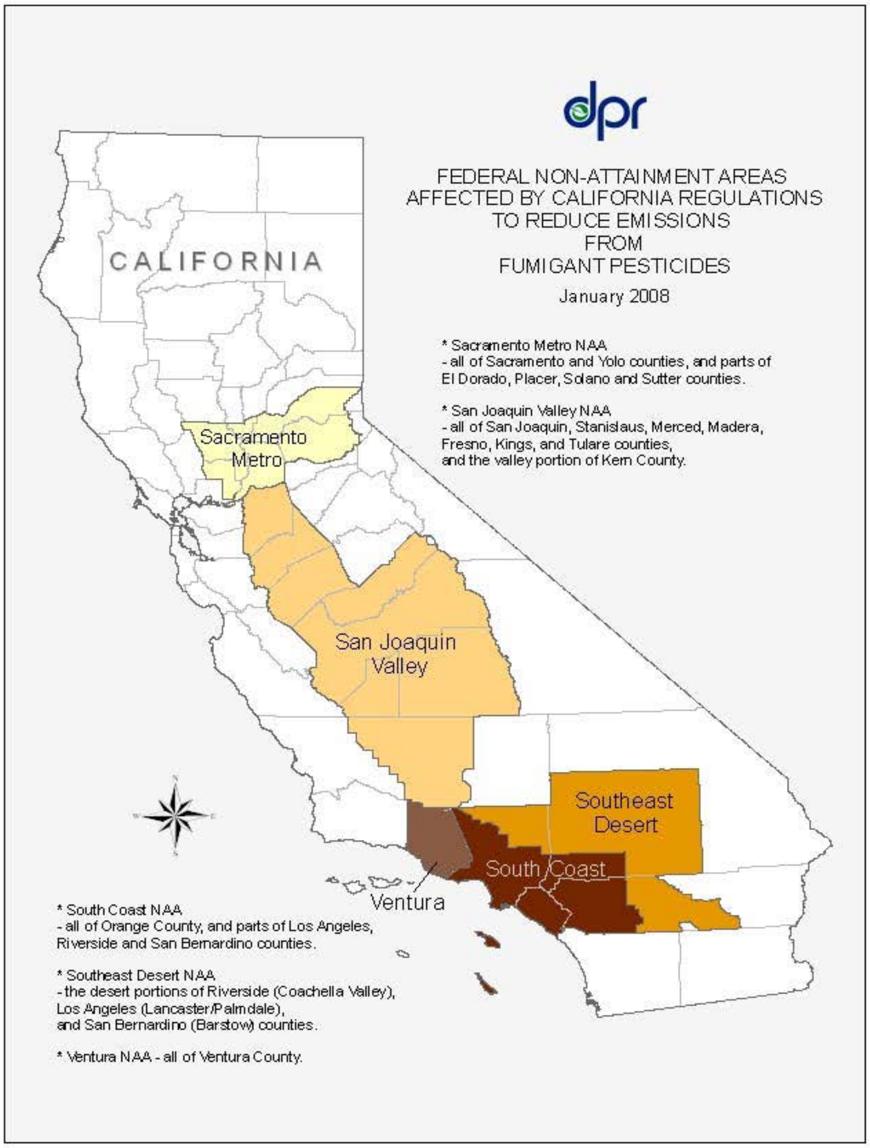


Figure 2a. Pesticide VOC emission inventory for the *Sacramento Metro* ozone NAA during May-October. The solid horizontal line indicates the SIP goal.

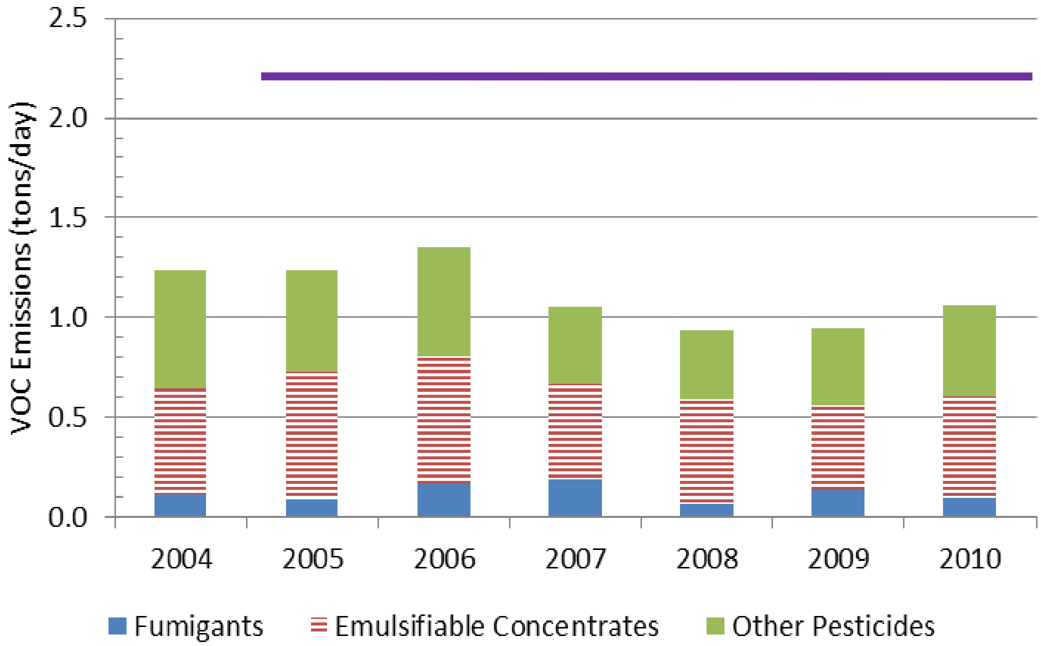


Figure 2b. Pesticide VOC emission inventory for the *South Coast* ozone NAA during May-October. The solid horizontal line indicates the SIP goal.

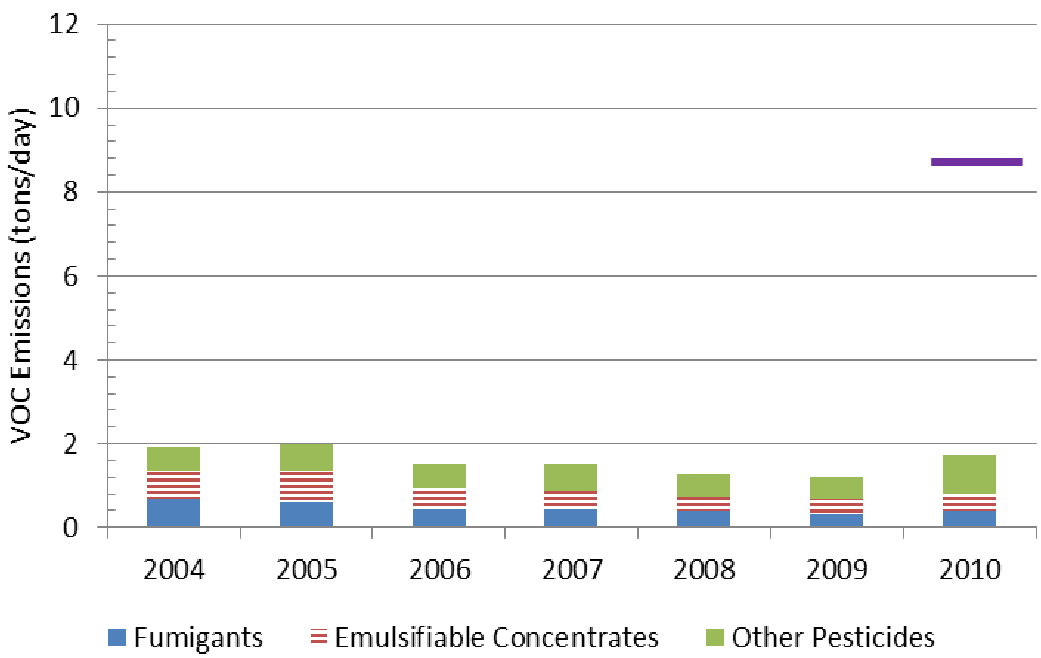


Figure 2c. Pesticide VOC emission inventory for the *Southeast Desert* ozone NAA during May-October. The solid horizontal line indicates the SIP goal.

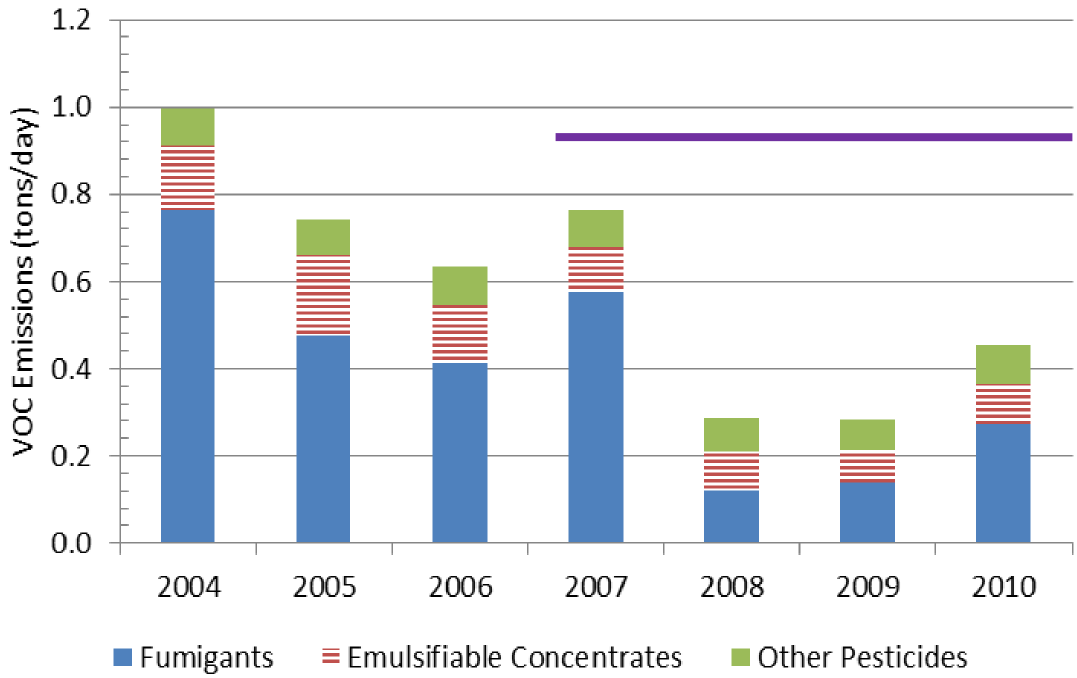


Figure 2d. Pesticide VOC emission inventory for the *Ventura* ozone NAA during May-October. The solid line indicates the phased in SIP goal.

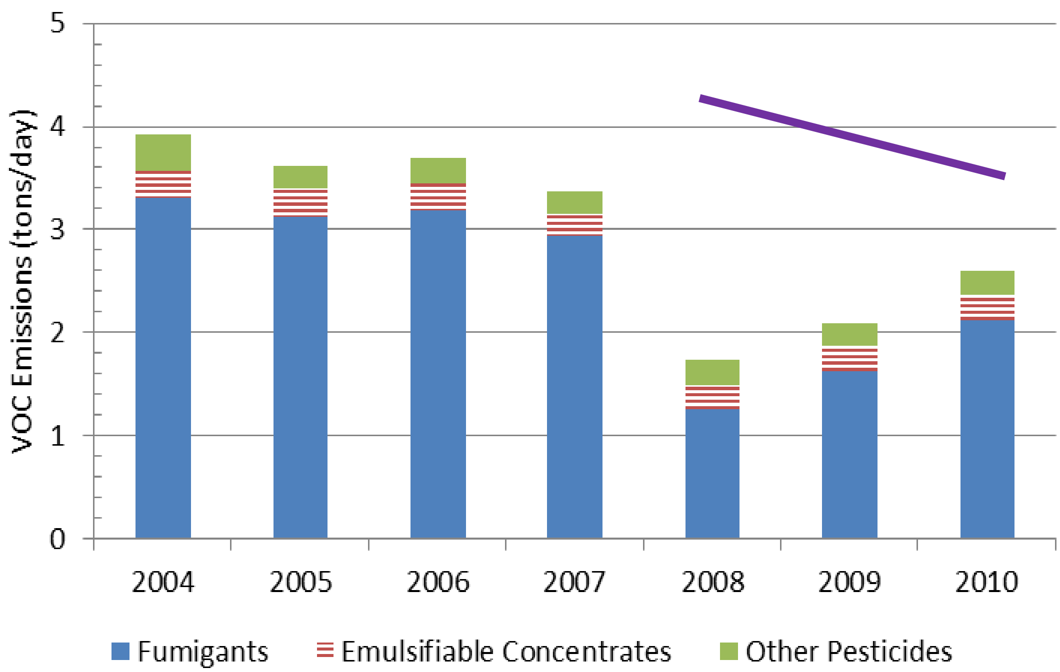


Figure 2e. Pesticide VOC emission inventory for the *SJV* ozone NAA during May-October. The solid horizontal line indicates the SIP goal. The dashed horizontal line indicates the trigger for a fumigant limit.

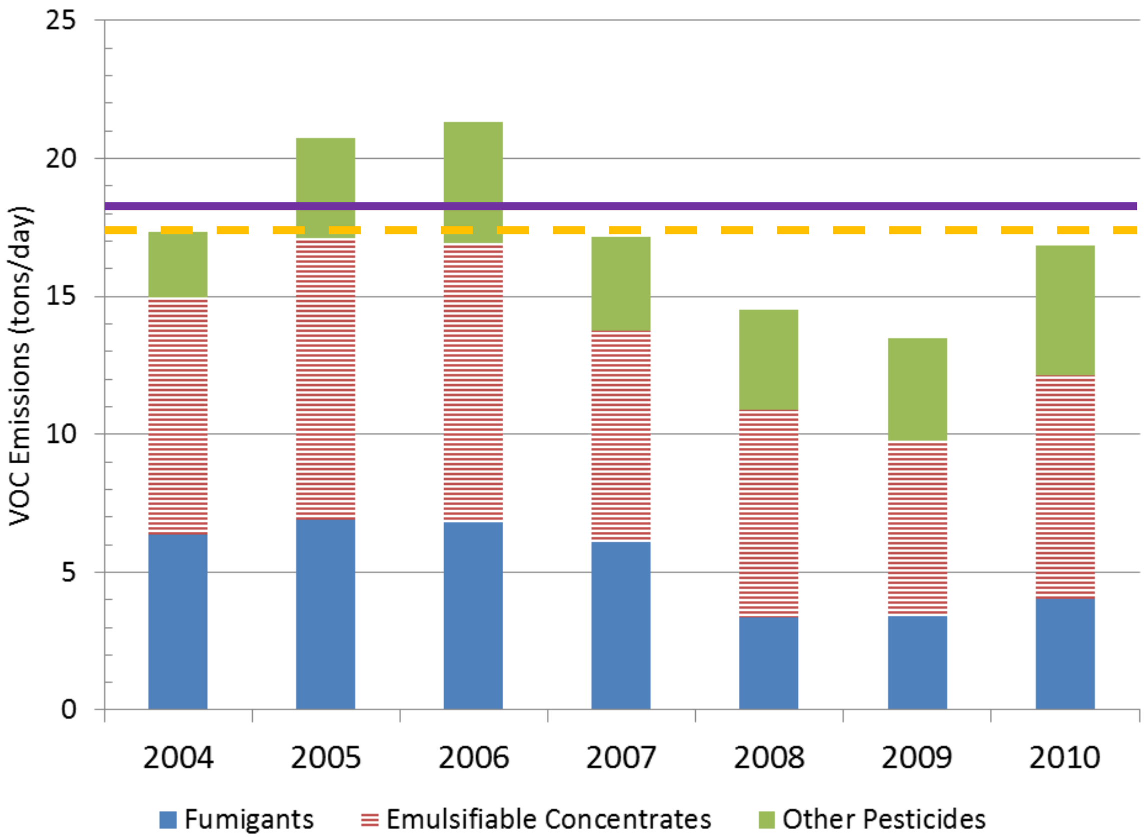


Figure 3. VOC emission trends of major nonfumigant pesticides in the SJV.

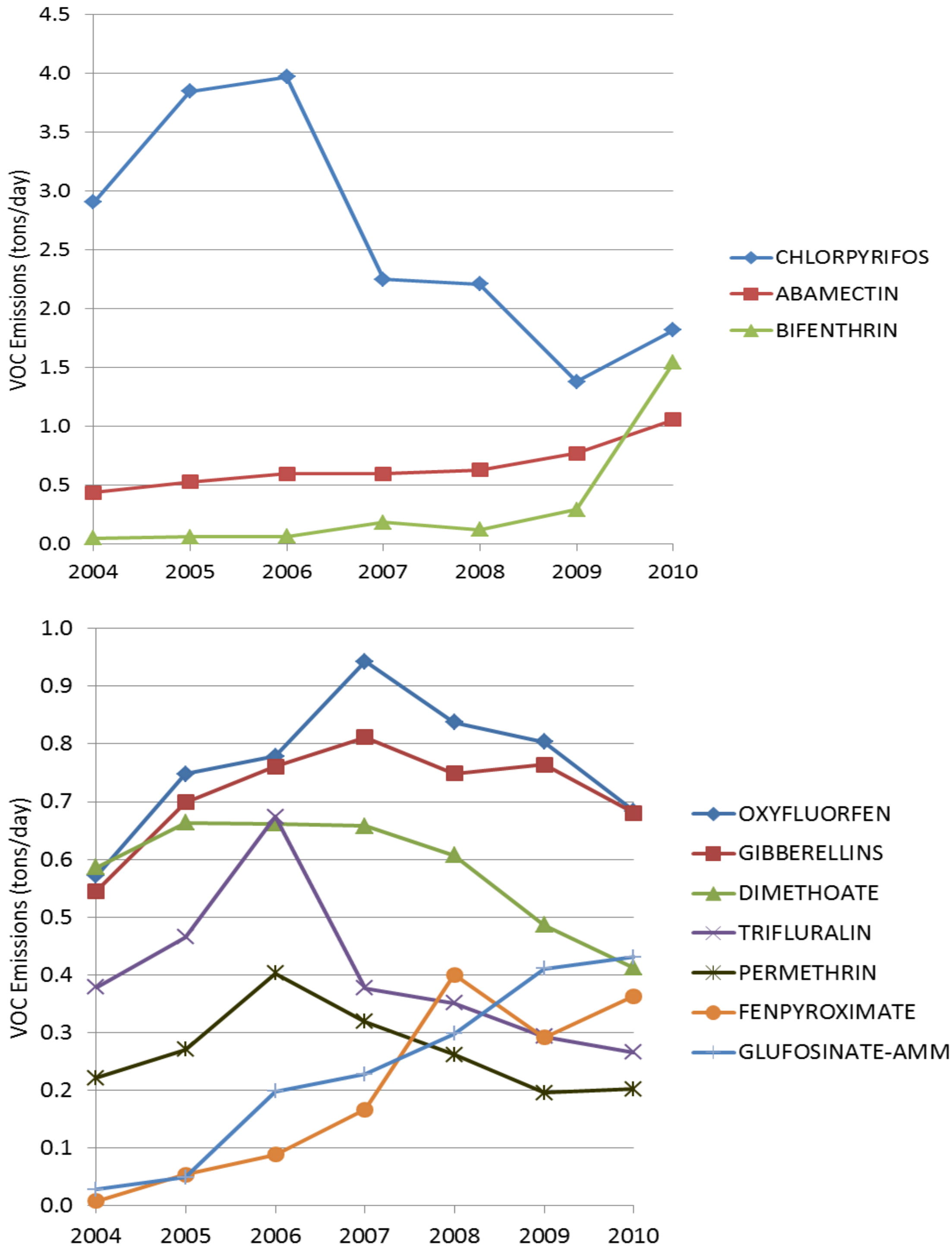


Figure 4a. Abamectin product and VOC emissions trends for the SJV. Emissions are expressed as pounds of VOC per pound of A.I. applied. An increasing trend indicates use of products with higher EPs over time. A decreasing trend indicates use of products with lower EPs over time.

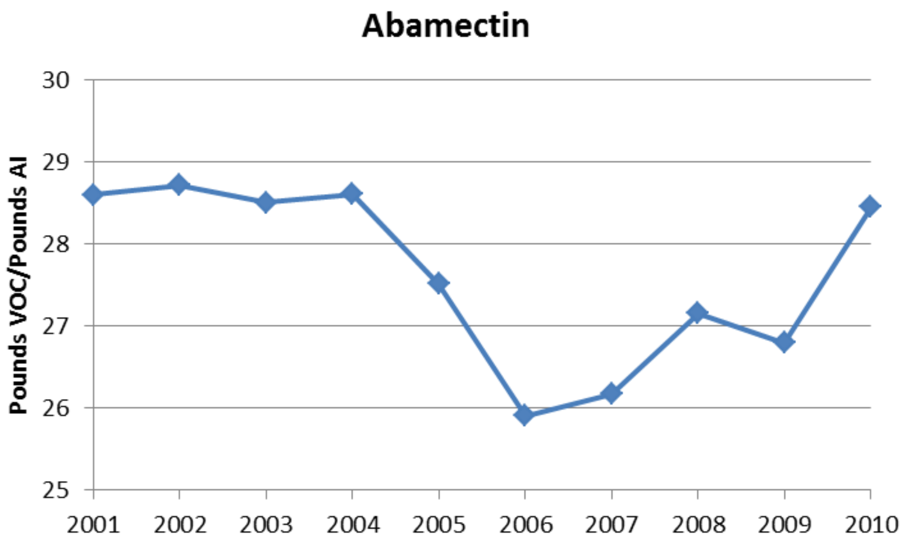


Figure 4b. Chlorpyrifos product and VOC emissions trends for the SJV. Emissions are expressed as pounds of VOC per pound of A.I. applied. An increasing trend indicates use of products with higher EPs over time. A decreasing trend indicates use of products with lower EPs over time.

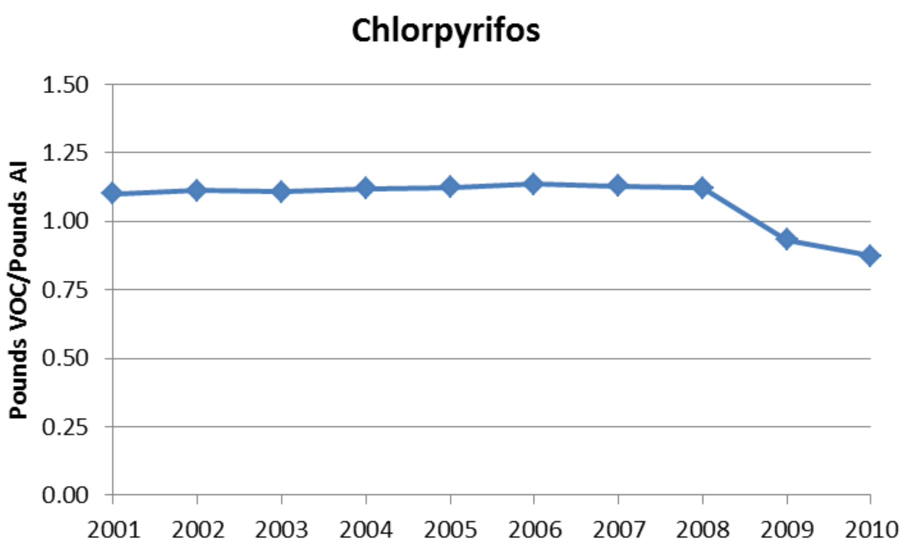


Figure 4c. Gibberellins product and VOC emissions trends for the SJV. Emissions are expressed as pounds of VOC per pound of A.I. applied. An increasing trend indicates use of products with higher EPs over time. A decreasing trend indicates use of products with lower EPs over time.

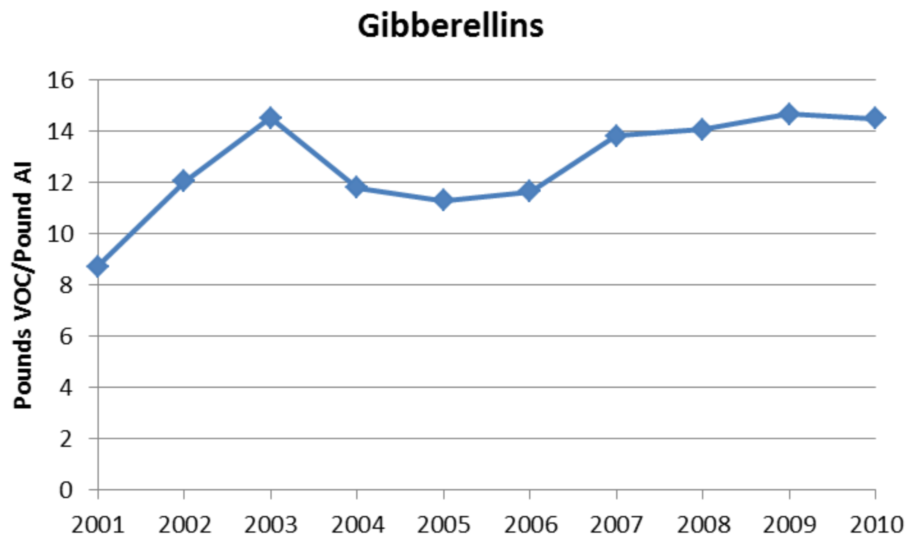


Figure 4d. Oxyfluorfen product and VOC emissions trends for the SJV. Emissions are expressed as pounds of VOC per pound of A.I. applied. An increasing trend indicates use of products with higher EPs over time. A decreasing trend indicates use of products with lower EPs over time.

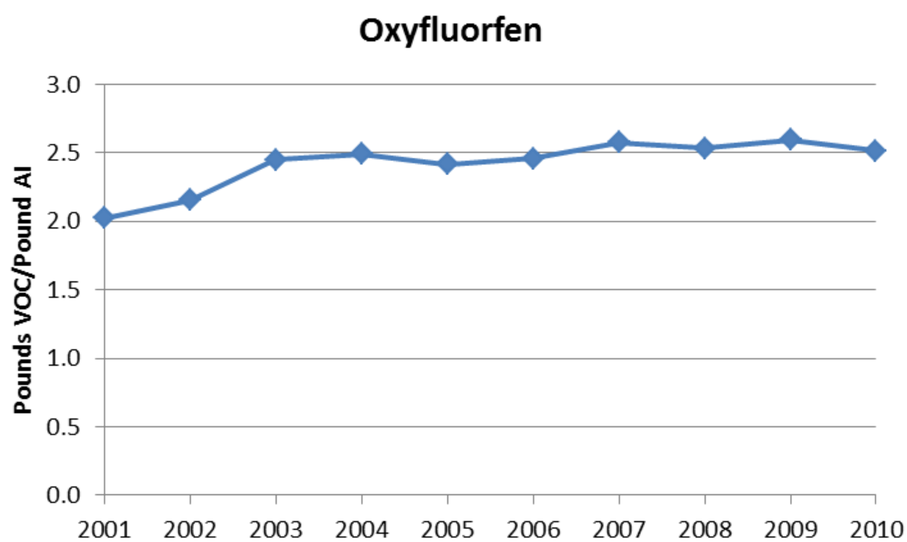


Figure 5a. Estimated pesticide VOC emissions for various reduction scenarios by A.I. for the SJV during May-October 2006, the highest year. Estimates include all crops, highest EPs, and all exceptions. The solid horizontal line indicates the SIP goal. The dashed horizontal line indicates the trigger for a fumigant limit. Actual pesticide VOC emissions for 2006 were 21.3 tons/day.

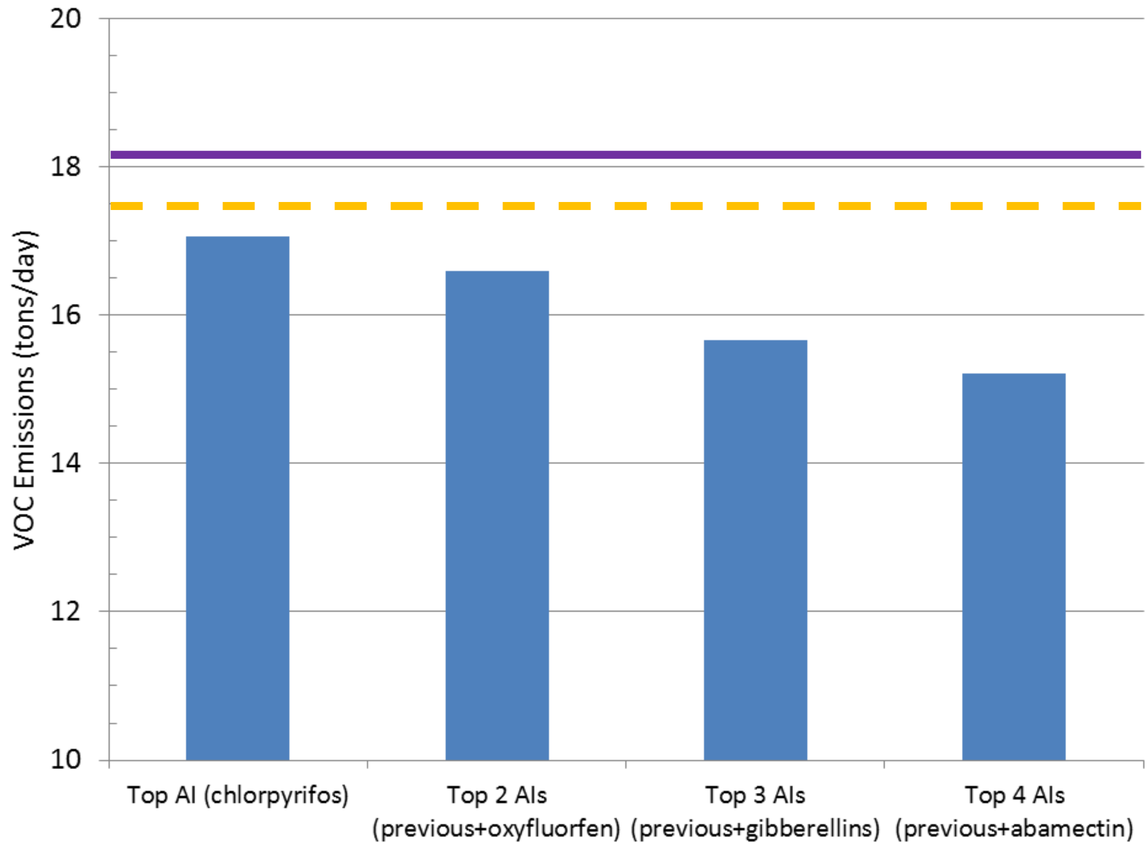


Figure 5b. Estimated pesticide VOC emissions for various reduction scenarios by crop for the SJV during May-October 2006, the highest year. Estimates include the top four AIs, highest EPs, and all exceptions. The solid horizontal line indicates the SIP goal. The dashed horizontal line indicates the trigger for a fumigant limit. Actual pesticide VOC emissions for 2006 were 21.3 tons/day.

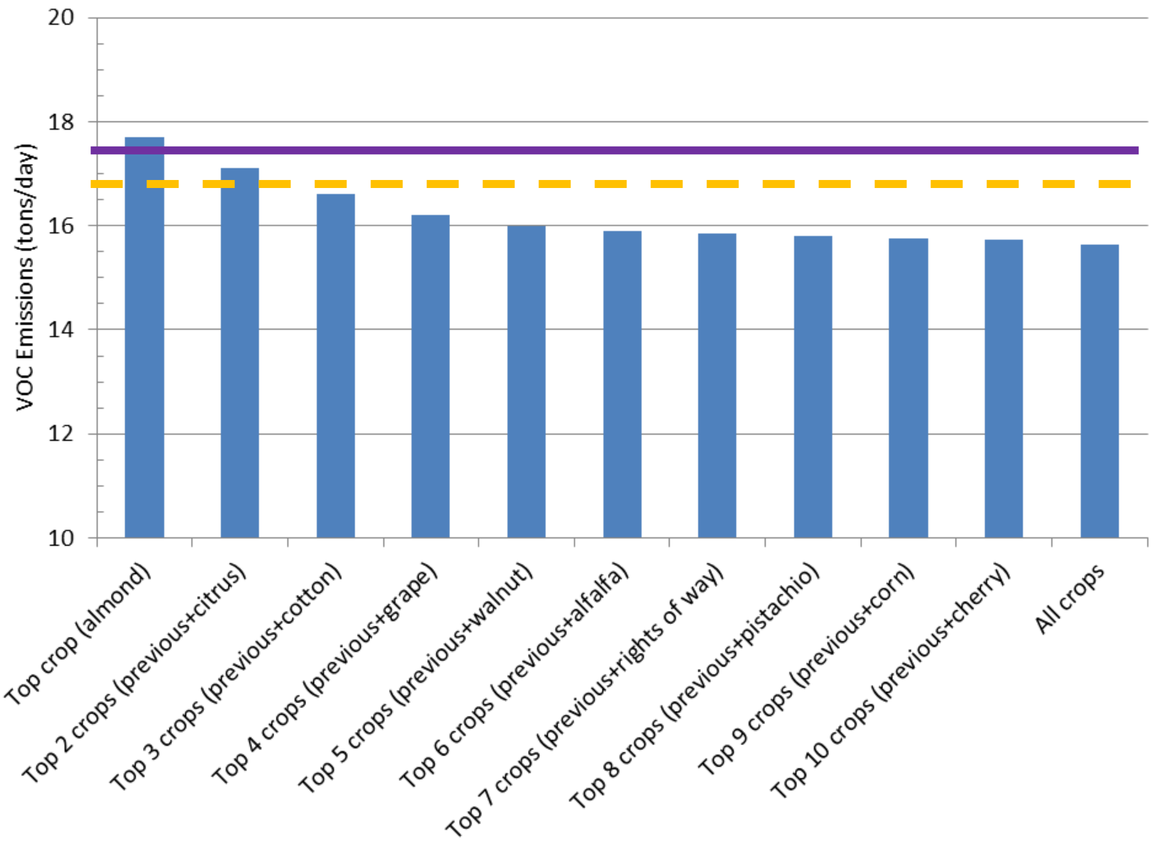
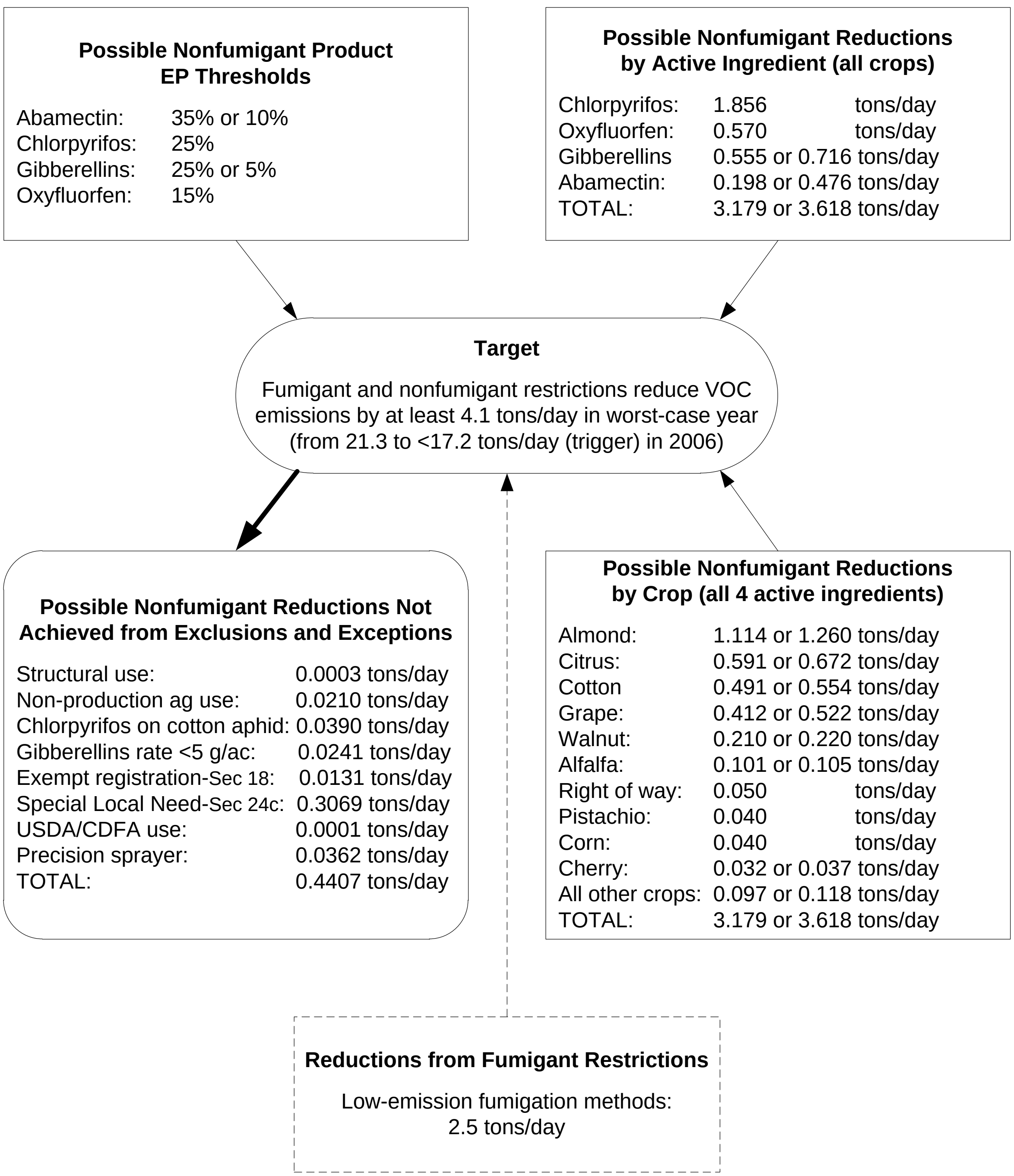


Figure 6. Overview of the possible scope and estimated VOC reductions for nonfumigant restrictions in the SJV during May-October. Reductions are achieved with restrictions on products that exceed EP thresholds. DPR must balance four factors to achieve the target VOC reductions from nonfumigant restrictions: the pesticide products (by A.I.) included, the EP thresholds selected, the crops included, and the exceptions included. Fumigant restrictions contribute additional reductions.



Appendix 1

Emulsifiable Concentrate Alternatives Analysis

Emulsifiable Concentrate Alternatives Analysis

by:
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Introduction

Under the federal Clean Air Act, the California Department of Pesticide Regulation (DPR) is required to track and reduce pesticidal sources of volatile organic compounds (VOC). When DPR proposed regulating emulsifiable concentrate (EC) pesticides that produce high levels of VOC emissions, CDFA's Office of Pesticide Consultation & Analysis contracted with fifteen University of California Cooperative Extension specialists to study alternatives to EC products. The primary goal was to determine the potential impact of EC product regulation on growers, i.e., what non-EC products growers would substitute and the differential cost of these alternatives.

Crops were selected on the basis of their overall economic importance to the state and included alfalfa, almond, broccoli, orange (as a general model for citrus), cotton, grapes (wine and other), lettuce (leaf and head), and walnut. For each crop, researchers selected a set of active ingredients (AI) which had the highest likelihood of being regulated. Using DPR's 2005 pesticide use report (PUR) database, emissions associated with particular active ingredients were summed for each study crop using pounds applied data and the respective emission potential for each product. Up to six AIs with the greatest emissions were selected for each crop (with the requirement that emissions for an AI comprise at least 1% of the total for a crop). Data for 2005-2007 were analyzed on an annual basis for the entire state and for all high-emission products with the exception of fumigants, adjuvants, and vertebrate pest control products.

By analyzing past usage patterns and with general knowledge of field use and product efficacy, UC researchers developed a set of alternatives that growers might use in the absence of EC-formulated products. Costs of alternatives and reductions in yield or crop quality were determined relative to standard grower practices. Changes in cost per acre and total cost changes per commodity are reported. It is hoped that the study will assist DPR in their effort to satisfy their mandated VOC emission-reduction goals in a manner that minimizes costs to California growers.

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Alfalfa

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California produces over 1.5 million acres of alfalfa hay, which is about 15% of the total alfalfa hay production in the United States. Alfalfa hay is produced in most counties in the state; this makes the crop unique in terms of geographical spread. However, the primary growing regions are the Sacramento Valley and San Joaquin Valley, which produce 60% of the state's alfalfa hay crop, and the desert region, which produces 20% of the state's alfalfa hay crop. The remaining 20% of the acreage is in the coastal and mountain areas. California Department of Pesticide Regulation has identified several insecticides and herbicides used on alfalfa as contributing volatile organic compounds (VOC) to air quality problems in California. DPR is proposing to regulate pesticides with evaporative potentials (EP) of greater than 20%. Alfalfa hay is the fourth largest VOC contributor of all agricultural commodities from emulsifiable concentrate formulations and contributed over 189,000 lbs of VOCs in 2005. The top six VOC producing pesticides and non-VOC producing alternative pesticides or formulations are discussed with regard to pest control activity and IPM potential.

Insecticides

The two insecticides listed are still useful products for alfalfa producers although they are both organophosphate insecticides and as such have been under scrutiny for several years and alternatives have been developed. However, the wide production area of alfalfa in California (without a doubt more widely produced than any other crop in the state) along with the high acreage means that the pest management challenges are varied and truly "one size does not fit all."

Chlorpyrifos – Lorsban 4E, with an EP value of 50, is used to manage Egyptian alfalfa weevil complex (*Hypera* spp.), several species of aphids including pea, *Acyrthosiphon pisum*, blue alfalfa aphid, *A. kondoi*, spotted alfalfa aphid, *Therioaphis maculate*, and cowpea aphid, *Aphis craccivora* and other miscellaneous insect pests (leafhoppers, grasshoppers, etc.) including some of the easier to kill lepidopterous larvae. For the weevil complex, there are several alternatives to Lorsban 4E (Table 1). Lorbsan 4E was widely used on alfalfa and was applied to 547,072, 443,385 and 386,338 acres in 2005, 2006 and 2007, respectively (Table 2). The amount of VOC produced by Lorsban 4EC varied from 274,400 lbs in 2005 to 207,000 lb in 2007 and accounted for 23% of the total VOC produced on alfalfa (Table 3). Only two insecticides (Lorsban Advanced and Mustang Max) of the eight possible replacements insecticides would be viable (Table 4). The use rate of the eight replacement insecticides alternatives was based on the 2006 PUR data. Alternative chlorpyrifos formulations to Lorsban 4E include Lock-ON, Lorsban Advanced and Lorsban 75WG. Lock-On, with an EP value of 21, is targeted to reduce off-site movement and to protect water quality. It apparently performs well on the alfalfa weevil complex but performance against other pests is unknown. Lorsban Advanced is a new chlorpyrifos formulation, which should perform comparably to the 4E formulation and should be a direct replacement. Lorsban 75WG is washed off by spring rain more easily than 4E formulation and thus requires an additional application. In addition, Lorsban 75WG is less effective in control of aphids in cotton and alfalfa trials and thus two applications of Lorsban 75WG will be required to replace one Lorsban 4E application. Thus, Lorsban Advanced and Mustang Max EW have the price and performance characteristics to make them direct replacement for Lorsban 4E on the weevil complex.

For the other alternatives, Imidan 70WP is very slow to provide control and somewhat erratic in efficacy (not very effective in cool weather, for instance). The registration of Furadan 4F is being/has been removed and thus it is not a viable alternative. The permethrin formulations (Pounce 25 WP and Ambush 25 W) are not preferred by growers because they are older generation pyrethroids, do not provide as long of control as newer products (the formulations do not protect the active ingredient from degradation and they are susceptible to wash-off from precipitation), and the wettable powder formulations can be difficult to apply. The pyrethroid products also have potential water quality issues and the drawback of being very broad-spectrum, thus destroying populations of natural enemies. This is important because alfalfa is known as the insectary for the San Joaquin Valley due to the habitat it provides for a wide range of natural enemies. Two of the most commonly used insecticide products in alfalfa (and a high proportion of this is targeting the weevil complex) are Steward EC (indoxacarb) and Warrior; however both of these present VOC issues.

Lorsban 4E is also a key product used for cowpea aphid control. This pest is becoming a more severe problem in the northern Central Valley. Lorsban Advanced will likely be a viable alternative although studies in alfalfa have not documented this. Studies conducted in cotton have shown this new formulation may not be quite as effective as the 4E formulation against cotton aphids. Similar data do not exist for cowpea aphids control in alfalfa. Dimethoate is a commonly used active ingredient for aphid control but its EC formulations cannot be considered alternatives.

For aphid control, all alternatives except Lorsban 75WG were estimated to require one application to provide similar control to Lorsban 4E (Table 4). The cost of material and application of the alternatives was estimated to range from approximately \$18 to \$71.50 per acre (Table 5). The elimination of Lorsban 4E would have cost alfalfa growers a projected \$37,572, \$8,690 and \$10,723 for 2005, 2006 and 2007, respectively with an average increase in cost of less that \$0.02 per acre (Table 6). Thus, the elimination of Lorsban 4E would have little economic impact in alfalfa.

Dimethoate – Dimethoate E267 and other EC formulations, with EP values of 39 to 63, are used primarily for pea aphid control and use is highest in the Imperial Valley. Chlorpyrifos is an alternative AI for aphid control. Lorsban 4E is a key product used for cowpea aphid control but the VOC properties of this product are problematic. Lorsban Advanced will likely be a viable alternative although studies have not documented the performance profile and two applications of Lorsban (Advanced, 75WG and Lock-On) would be required to replaced one application of Dimethoate (Table 7). However, Lorsban 75WG is too costly to be used in alfalfa. Other alternatives for aphid management in alfalfa are limited. Materials such as neonicotinoid products are effective on aphids but not available for use on alfalfa. Host plant resistance offers good control, under most environmental conditions, for spotted alfalfa aphid and blue alfalfa aphid. Pea aphid and the recent alfalfa pest, cowpea aphid, should be controlled upon reaching damaging levels with insecticides.

The cost of material and application of the alternatives was estimated to range from approximately $43.16 to $71.50 per acre (Table 8). The elimination of Dimethoate would have cost alfalfa growers a projected $1,888,142, $1,825,370 and $1,954,171 for 2005, 2006 and 2007, respectively, with an average increase in cost of about $13.50 per acre (Table 9).

Herbicides

The four alfalfa herbicides listed on the VOC registry are very important herbicides needed to maintain weed free alfalfa. The alfalfa industry markets approximately 70% of California hay to dairies and 20% to the pleasure horse and other animal markets and all are motivated to buy weed free hay. The market price for alfalfa hay is established by several factors, primarily nutrient value and digestibility, which are impaired by the presence of weeds. In addition, poisonous weeds, that are not uncommon in alfalfa, can be problematic. High quality, weed free hay commands the highest price and is ranked as a top pest management priority. There are a limited number of herbicides available for alfalfa, which generally have a specific time during the year, and weed spectrum they are effective on. The herbicides listed on the VOC registries are important in controlling specific weeds at different times during the season and necessary to produce the highest quality hay.

Hexazinone – Velpar L, with an EP value of 37.6, is used for broad leaf and groundsel control in established alfalfa during the dormant period from November to January (Tables 10 and 11). Its use is extensive across all California alfalfa production areas. It is an important herbicide since it controls a broad range of weeds plus an important tool to control common groundsel *Senecio vulgaris*, a poisonous weed of alfalfa. Because of its effectiveness on most broadleaf weeds and soil residual, it has significant use during the winter dormant season. Velpar L was applied to 89,590 – 117,098 acres between 2005 and 2007 (Table 13) and accounted for 5.7% – 8.1% of the total VOC produced on alfalfa between 2005 and 2007 (Table 14).

Alternatives:
Velpar 75DF® is a new registered formulation of hexazinone without VOC issues. In test situations, Velpar 75DF had the same level of pre-emergent weed control as Velpar L (Tables 12, 15 and 16). Thus, there can be a direct substitution of Velpar 75DF for Velpar L. Sencor 75 DF (metribuzin) is a pre-emergent herbicide also registered for alfalfa and since it is a dry flowable formulation, it should have a low EP value (the EP value is not known at this time). It could be considered as a direct substitute in some regions. However, it has limited control of common groundsel and other winter annual weeds of alfalfa. Chateau (fumioxazin) was registered in 2008 and will control many of the same weeds that Velpar L can. It has a different mode of action than Velpar 75DF or Sencor 75DF, making it a good tool for resistant management, plus it has a shorter crop rotation interval. Chateau is principally a soil residual herbicide at the use rate in alfalfa and therefore cannot replace the same level of control on emerged weeds as Velpar L. Thus, there are adequate alternatives for Velpar L. The cost of materials and application of the alternatives was estimated to range from $25.47 to $112.67 per acre (Table 16). The elimination of Velpar L would have cost alfalfa growers $390,177, $509,978 and $395,336 for 2005, 2006 and 2007, respectively, with an average increase in cost of about $4.36 per acre (Table 17). Thus, the elimination of Velpar L would have an adverse impact on alfalfa growers.

Sethoxydim (*Poast1.5EC/Arrow 2EC*) **Clethodim** (*Select 2EC/Select Max*) – Poast 1.5EC, with an EP value of 71, and **Clethodim** – Select 2EC, with an EP value of 79, are two herbicides with the same mode of action and are used to control similar grass weeds in seedling and established alfalfa (Tables 10 and 11). Typically, two applications of Poast 1.5EC or Select 2EC are used annually. 47,147, 29,904 and 20,059 acres were treated with Poast 1.5 EC in 2005, 2006 and 2007, respectively while. Select 2EC was used on 87,365, 108,543 and 61,361 acres in 2005, 2006 and 2007, respectively (Table 13). Poast 1.5EC and Select 2EC are the only post-emergent selective herbicides registered for grass control. Between 2005 and 2007, Poast 1.5 EC accounted for 2.7% to 5.8% of the total VOC while Select 2EC accounted for 3.2% to 8.4% of the total VOC produced on alfalfa (Table 14). Poast 1.5EC and Select 2EC are very safe to all growth stages from seedling to established plants and therefore have a wide window of application timings. They have no soil activity, which is an advantage for crop rotations. Poast 1.5EC and Select 2EC are also important in controlling glyphosate resistant grasses and managing for ALS herbicide resistant weeds. The herbicides can be substituted for one another for summer and winter annual grass control. However, comparing relative importance, clethodim would be the more important of the two because it controls *Poa* annual bluegrass where sethoxydim does not. Losing both herbicides would have significant economic impact and leave the industry without good viable options for post emergent grass control.

Alternatives:
Select Max ® was recently registered for alfalfa. It contains the same active ingredient, clethodim, as Select 2EC. Select Max has a lower and acceptable EP value and would be a viable and direct substitute for both Poast 1.5EC and Select 2EC. Select Max has the same range of activity as Select 2EC. Raptor 1E, imazamox, has post emergent activity and controls grasses and broadleaf weeds of alfalfa (Tables 10 and 12). It has potential for use in some areas. Raptor will not control the entire spectrum of grass species of Select 2EC or Poast 1.5EC and has a longer plant back restriction for crops grown following alfalfa. It is an ALS herbicide, which is a family of chemistry recognized for developing resistant quickly if used continuously and therefore would not be stongly recommended for substitute status. The cost of material and application of the alternatives was estimated to range from $15.24 per acre for Select Max to $40.20 per acre for Raptor 1E (Table 19). The elimination of Poast 1.5EC would have resulted in a reduction of cost to alfalfa growers from $2,444,785, $1,549,787 and $1,039,553 for 2005, 2006 and 2007, respectively, with an average decrease in cost of about $1.15 per acre (Table 20). The elimination of Select 2EC would have resulted in a reduction of cost to alfalfa growers from $1,653,148, $2,053,894 and $1,161,104 for 2005, 2006 and 2007, respectively with an average decrease in cost of about $18.92 per acre (Table 20). Thus, the elimination of Poast 1.5EC or Select 2EC would have no adverse effect on productions costs for alfalfa growers.

EPTC – Eptam 7-E, with an EP value of 39, is primarily used for suppression of yellow and purple nutsedge. It also controls many annual grasses and broadleaf weeds in established alfalfa (Tables 10 and 11). In established alfalfa, it is applied between cuttings in the irrigation water. Eptam 7-E can also be used as a pre-plant incorporated herbicide before planting alfalfa. Once a primary herbicide for seedling alfalfa, it has lost favor to newer post-emergent herbicides that are broader spectrum. Eptam 7-E was applied to 19,973 – 34,889 acres between 2005 and 2007 (Table 13) and accounted for 3.4% – 7.0% of the total VOC produced on alfalfa between 2005 and 2007 (Table 14).

Alternatives:
Because of its usefulness in suppressing nutsedge, there are few herbicide substitutes and none without ground water restrictions and plant back limitations. Possible alternatives to Eptam 7-E include

Solicam 80DF, norflurazone and Sandea 75WDG, halosulfuron. Solicam 80DF, with an EP value of 1, is a pre-emergent soil residual herbicide. Solicam 80DF is active on nutsedge species and many other weeds but has restrictions in certain counties due to crop injury in lighter soil types. It also is restricted in ground water pest management areas, a significant limiting factor. Sandea 75WDG, with an EP value of 3.7, received alfalfa registration in 2007 for nutsedge control. Unlike Eptam 7-E, it is applied post-emergent to nutsedge. Sandea 75WDG has been found to injure alfalfa in the central valley counties and has not been widely accepted. Eptam 20G, with an EP value of 20, could be used as pre-plant incorporated herbicide and a direct substitute for Eptam 7-E. The cost of material and application of the alternatives was estimated to range from $49.48 per acre for Sandra 75WDG to $97.79 per acre for Solicam (Table 19). The elimination of Eptam 7-E would have increased production costs for alfalfa growers $389,896, $223,207 and $299,507 for 2005, 2006 and 2007, respectively, with an average increase of about $11.18 per acre (Table 24). Thus, the elimination of Eptam 7-E would have an adverse economic effect on alfalfa growers.

Tables

Table 1. VOC producing insecticides and alternatives

	Materials	Yield loss (%)	Quality change
VOC Producing Pesticide	**Lorsban 4E**	10-40%	
Alternative 1	Imidan 70WP	20-40%	
Alternative 2	Furadan 4F	--	
Alternative 3	Lorsban 75WG	20-40%	
Alternative 4	Lorsban Advanced	10-40%	
Alternative 5	Lock-On	20-40%	
Alternative 6	Mustang Max EW	--	
Alternative 7	Pounce 25WP	20-40%	
Alternative 8	Ambush 25WP	20-40%	
VOC Producing Pesticide	**Dimethoate 2.67 EC, Dimethoate 4E and others**	10-40%	
Alternative 1	Lorsban 75WG	10-40%	
Alternative 2	Lorsban Advanced	10-40%	
Alternative 3	Lock-On	10-40%	

Table 2. VOC producing insecticides: Acres used and rate of application

Chemical name	Trade name	Pest(s) controlled	No. acres treated[a] 2005	2006	2007	Months of appls.	Rate form ac/ appl[b]	% control
Chlorpyrifos	Lorsban 4E	Alfalfa weevil complex, Aphids, leafhoppers	547,072	443,385	386,338	Jan. – Nov.	2 pt	75 – 90%
Dimethoate	Dimethoate 2.67 EC, Dimethoate 4E and others	Pea, blue alfalfa, spotted alfalfa, and cowpea aphids	139,089	134,465	143,953	March – Nov.	1.5 pts.	75 – 90%

[a] Use rates from 2005 to 2007 pesticide use report data.

[b] Formulated amount based on 2005 pesticide use report data i.e. active ingredient/ac modified to formulated amount/ac.

Table 3. Amount (lbs) and percent of total VOC emission produced by active ingredients for 2005 through 2007 in alfalfa

Chemical name	Trade name	2005 Amount[a]	2005 Percent	2006 Amount[a]	2006 Percent	2007 Amount[a]	2007 Percent
Chlorpyrifos	Lorsban 4E	274.4	24.6%	230.7	21.1%	207.0	22.6%
Dimethoate	Dimethoate 2.67 EC, Dimethoate 4E and others	61.4	5.5%	62.9	5.7%	70.7	7.7%

[a] Amount times 1000 pounds from 2005 to 2007 pesticide use report data and Dept of Pesticide Regulation.

Table 4. Alternative insecticides to Lorsban 4E - Application details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl.[a]	Appl. method	Percent control[b]
Phosmet	Imidan 70WP	Alfalfa weevil complex	1	Jan. – May	1 lb	Ground/ Air	80 – 90%
Carbofuran	Furadan 4F	Alfalfa weevil complex	1	Jan. – May	2 pt	Ground/ Air	80 – 90%
Chlorpyrifos	Lorsban 75WG	Pea, blue alfalfa, spotted alfalfa, cowpea aphids,	2	Jan. – Nov.	1.33 lb	Ground/ Air	70 – 90%
		Alfalfa weevil complex	1	Jan-May	1.33 lb.	Ground/ Air	60-70%
Chlorpyrifos	Lorsban Advanced	Pea, blue alfalfa, spotted alfalfa, cowpea aphids,	1	Jan. – Nov.	2 pts.	Ground/ Air	70 – 90%
		Alfalfa weevil complex	1	Jan-May	2 pts.	Ground/ Air	80-90%
Chlorpyrifos	Lock-on	Alfalfa weevil complex	1	Jan-May	2 pts.	Ground/ Air	80-90%
		Pea, blue alfalfa, spotted alfalfa, cowpea aphids,	1	Jan. – Nov.	2 pts.	Ground/ Air	70 – 90%
Permethrin	Pounce 25WP	Alfalfa weevil complex	1	Jan-May	12.8 oz.	Ground/ Air	60-70%
Permethrin	Ambush 25W	Alfalfa weevil complex	1	Jan-May	12.8 oz.	Ground/ Air	60-70%
Zeta-cypermethrin	Mustang Max EW	Alfalfa weevil complex	1	Jan-May	4.0 fl. oz.	Ground/ Air	70-80%

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Lorsban 4E.

Table 5. Cost of Lorsban 4E and replacement cost of alternative insecticides for Lorsban 4E

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac [a]
Chlorpyrifos	Lorsban 4E	12.80	pt	1	Ground/ Air	12.80	21.80
Phosmet	Imidan 70WP	12.39	lb	1	Ground/ Air	12.39	21.39
Carbofuran	Furadan 4F	13.77	pt	1	Ground/ Air	27.53	36.53
Chlorpyrifos	Lorsban 75WG	20.10	lb	2	Ground/ Air	26.73	71.47
Chlorpyrifos	Lorsban Advanced	7.46	pt	1	Ground/ Air	14.92	23.92
Chlorpyrifos	Lock-On	6.29	pt	1	Ground/ Air	12.58	21.58
Permethrin	Pounce 25 WP	0.99	oz	1	Ground/ Air	12.67	21.67
Permethrin	Ambush 25 W	0.89	lb	1	Ground/ Air	11.39	20.39
Zeta-cypermethrin	Mustang Max EW	2.18	fl.oz	1	Ground/ Air	8.72	17.72

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 6. Replacement cost of alternative scenarios for Lorsban 4E

Target pest(s)	Alternative	Trade name	Cost per acre	Percent of Lorsban 4E replacement acreage	Replacement cost[a] 2005	2006	2007
Alfalfa weevil complex	Alternative 1	Imidan 70WP	21.39	1	82,638	94,840	117,019
Alfalfa weevil complex	Alternative 2	Furadan 4F	36.53	5	705,685	809,887	999,282
Pea, blue alfalfa, spotted alfalfa, cowpea aphids, Alfalfa weevil complex	Alternative 3	Lorsban 75WG	71.47	1	276,100	316,870	390,970
Pea, blue alfalfa, spotted alfalfa, cowpea aphids, Alfalfa weevil complex	Alternative 5	Lorsban Advanced	23.92	40	3,696,482	4,242,308	5,234,385
Pea, blue alfalfa, spotted alfalfa, cowpea aphids, Alfalfa weevil complex	Alternative 6	Lock-on	21.58	1	83,372	95,682	118,058
Alfalfa weevil complex	Alternative 7	Mustang Max EW	17.72	50	3,422,955	3,928,391	4,847,058
Alfalfa weevil complex	Alternative 8	Pounce 25WP	21.67	1	41,864	48,045	59,281
Alfalfa weevil complex	Alternative 9	Ambush 25 WP	20.39	1	39,391	45,208	55,779
				100%	8,429,741	9,674,483	11,936,892
			Lorsban 4E cost		8,422,168	9,665,793	11,926,169
			Difference in cost from change		7,572	8,690	10,723

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 7. Alternative insecticides to Dimethoate 2.67 EC, Dimethoate 4E and others - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl [a]	Appl method	% control [b]
Chlorpyrifos	Lorsban 75WG	Pea, blue alfalfa, spotted alfalfa, cowpea aphids	2	Jan. – Nov.	1.33 lb	Ground/ Air	70 – 90%
Chlorpyrifos	Lorsban Advanced	Pea, blue alfalfa, spotted alfalfa, cowpea aphids,	2	Jan. – Nov.	2 pts.	Ground/ Air	70 – 90%
Chlorpyrifos	Lock-on	Pea, blue alfalfa, spotted alfalfa, cowpea aphids,	2	Jan. – Nov.	2 pts.	Ground/ Air	70 – 90%

[a] Most use rates based on 2005 pesticide use report data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Dimethoate 2.67 EC, Dimethoate 4E and others.
[c] Restrictions in water protection areas.

Table 8. Cost of Dimethoate 2.67 EC and replacement cost of alternative insecticides for Dimethoate 2.67

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl method	Total material cost/ac	Total material & appl. cost/ac [a]
	Dimethoate 2.67 EC	5.36	pt	1.5	Ground/ Air	8.04	34.08
Chlorpyrifos	Lorsban 75WG	20.10	lb	1.3	Ground/ Air	26.73	71.47
Chlorpyrifos	Lorsban Advanced	7.46	pt	2	Ground/ Air	14.92	47.84
Chlorpyrifos	Lock-on	6.29	pt	2	Ground/ Air	12.58	43.16

[a] Total material cost per treated acre plus application cost of $9.00 per acre times number of applications.

Table 9. Replacement cost of alternative scenarios for Dimethoate 2.67 EC, Dimethoate 4E and others

Target Pest(s)	Alternatives	Trade name	Cost per acre	Percent of Dimethoate 2.67EC, Dimethoate 4E and others replacement acreage	Replacement cost[a] 2005	2006	2007
Pea, blue alfalfa, spotted alfalfa, cowpea aphids	Alternative 1	Lorsban 75WG	71.47	1	99,401	96,097	102,877
Pea, blue alfalfa, spotted alfalfa, cowpea aphids	Alternative 2	Lorsban Advanced	47.84	90	5,988,616	5,789,525	6,198,040
Pea, blue alfalfa, spotted alfalfa, cowpea aphids	Alternative 2	Lock-on	43.16	9	540,277	522,316	559,171
				100	6,628,295	6,407,938	6,860,089
			Cost of Dimethoate 2.67EC		4,740,153	4,582,567	4,905,918
			Difference in cost from change		1,888,142	1,825,370	1,954,171

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 10. VOC producing herbicides and alternatives

	Materials	Detail table reference	Comments	Yield and stand loss[1] (%)	Quality change[2](high, % medium, low, none) change price[3]
VOC Producing Pesticide(s)	**Velpar 2WDL**	**2.1**	**Contact and soil residual activity**	**10-30%**	**High 30-60%**
Alternative 1	Metribuzin 75DF Sencor®	3.1	Contact and soil		
Alternative 2	Velpar 75DF	3.2	New Formulation		
Alternative 3	Chateau	3.4	residual properties		
VOC Producing Pesticide(s)	**Poast 1.5EC**	**2.2**	**No soil residual**	**10-30%**	**High 30-50%**
Alternative 1	Select Max 1E	3.3	New formulation/ no soil residual		
Alternative 2	Raptor 1E	3.7	Long soil residual		
VOC Producing Pesticide(s)	**Select 2EC**	**2.3**		**10-30%**	**High 30-50%**
Alternative 1	Select Max 1E	3.3	New formulation/ no soil residual		
VOC Producing Pesticide(s)	**Eptam 7-E**	**2.4**		**10-40%**	**Medium 10-50%**
Alternative 1	Eptam 20G	3.5	Irrigation timing to application. Product availability		
Alternative 2	Solicam	3.6	Ground water issues, plant back rotation		
Alternative 3	Sandea 75WDG	3.8	Crop injury/ yield loss		

[1]Yield and Stand Loss = Stand loss due to Weed Competition
[2]Quality Change = Lowering of forage quality due to excessive weeds in hay
[3]Change price = lower market price and demand by livestock type due to poor forage quality

Table 11. VOC producing herbicides application details for: Velpar L, Poast 1.5EC, Select 2EC and Eptam 7-E

	Chemical name	Trade name	Pest(s) controlled	Number of applications	Months of application(s)	Rate per treated acre per application	Application method (ground or air)	Percent control
2.1	hexazinone	Velpar L	BL Weeds + common groundsel	1	Nov-Jan	0.25-1.5 lb ai	Ground/Air	> 90%
2.2	sethoxydim	Poast 1.5EC	Foxtail,Watergrass, Annual / perennial grasses	2	March-Sept	0.5 lb ai	Ground/Air	60-80%
2.3	clethodim	Select 2EC	Foxtail,Watergrass, Annual / perennial grasses	2	March-Sept	0.1 lb ai	Ground /Air	60-80%
2.4	EPTC	Eptam 7E	Annual grasses & nutsedge	1-4	March- Sept	2-3 lb ai	Ground/ water run	60-80%

Table 12. Alternatives herbicides application detail for: Velpar L, Poast 1.5EC, Select 2EC and Eptam 7-E

`	Chemical/generic name	Trade name	Pest(s) controlled	Number of applications	Months of application(s)	Rate per treated acre per application	Application method	Percent control
3.1	Metribuzin	Sencor 75DF	Broadleaf Weeds Groundsel	1	Nov-Jan	0.375 – 0.495 lb ai	Ground/Air	> 80%
3.2	Hexazinone	Velpar 75DF	Broadleaf weeds Groundsel	1	Nov-Jan	0.23 – 1.5 lb ai	Ground/Air	> 80%
3.3	Clethodim	Select Max 1E	Grasses	1	Jan- Sept	0.03 – 0.04 lb ai	Ground/Air	> 80%
3.4	Fumioxazin	Chateau	Broadleaf Weeds Groundsel	2	Nov-Jan	0.125 lb ai	Ground /Air	>80%
3.6	Norflurazone	Solicam 80DF	Annual weeds, grasses & Nutsedge	1-2	March- Sept	1.0-2.0 lb ai	Ground/Air	60-80
3.7	Imazamox	Raptor 1E	Annual grasses and BL weeds	1	March- Sept	.031-.047	Ground/Air	60-80
3.8	Halosulfuron	Sandea	Nutsedge sp	1	May- Aug	.047	Ground	60-75

Table 13. VOC producing herbicides: Acres used and rate of application

Chemical name	Trade name	Pest(s) controlled	No. acres treated[a] 2005	2006	2007	Months of appls.	Rate form ac/ appl[b]	% control
Hexazinone	Velpar 2WDL	Broadleaf weeds and common groundsel	89,590	117,098	90,775	Nov. – Jan.	56.00 fl. oz/ac	>90%
Sethoxydim	Poast 1.5 EC	Foxtail, Waltergrass, annual/perennial grasses	47,174	29,904	20,059	March. – Sept.	85.33 fl. oz/ac	60-80%
Clethodim	Select 2EC	Foxtail, Waltergrass, annual/perennial grasses	87,365	108,543	61,361	March. – Sept.	27.24 fl. oz/ac	60-80%
EPTC	Eptam 7-E	Annual grasses Nutsedge sp.	34,889	19,973	26,801	March – Sept.	114.28 fl. oz/ac	60-80%

[a] Use rates from 2005 to 2007 pesticide use report data.
[b] Formulated amount based on 2005 pesticide use report data i.e. active ingredient/ac modified to formulated amount/ac.

Table 14. Amount (lbs) and percent of total VOC emission produced by active ingredients for 2005 through 2007 in alfalfa

		2005		2006		2007	
Chemical name	Trade name	Amount[a]	Percent	Amount[a]	Percent	Amount[a]	Percent
Hexazinone	Velpar L	63.3	5.7	88.5	8.1	66.1	7.2
Sethoxydim	Poast 1.5 EC	65.2	5.8	39.9	3.6	25.1	2.7
Clethodim	Select 2EC	88.1	7.9	92.4	8.4	29.6	3.2
EPTC	Eptam 7-E	78.4	7.0	37.1	3.4	55.5	6.1

[a] Amount times 1000 pounds from 2005 to 2007 pesticide use report data and Dept. of Pesticide Regulation.

Table 15. Alternative herbicides to Velpar L - Application details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl.[a]	Appl. method	Percent control[b]
Metribuzin	Sencor 75 DF	Broadleaf weeds and common groundsel	1	Nov. – Jan.	3.33 lb/ac	Ground/Air	> 80%
Hexazinone	Velpar 75 DF		1	Nov. – Jan.	1.15 lb/ac	Ground/Air	> 90%
Fumioxazin	Chateau		2	Nov. – Jan.	0.125 lb/ac	Ground/Air	> 80%

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.

[b] Compared to Velpar 2WDL.

Table 16. Cost of Velpar L and replacement cost of alternative herbicides for Velpar L

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac[a]
Hexazinone	Velpar L						
Metribuzin	Sencor 75 DF	31.10	lb	3.33	Ground/Air	103.67	112.67
Hexazinone	Velpar 75 DF	34.58	lb	1.15	Ground/Air	39.88	48.88
Fumioxazin	Chateau	135.00	lb	0.25	Ground/Air	33.75	42.75

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 17. Replacement cost of alternative scenarios for Velpar L

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Velpar 2WDL replacement acreage	Replacement cost[a] 2005	2006	2007
Broadleaf weeds and common groundsel	Alternative 1	Sencor 75 DF	112.67	10	1,009,382	1,319,303	1,022,727
	Alternative 2	Velpar 75 DF	48.88	65	2,846,589	3,720,606	2,884,225
	Alternative 3	Chateau	42.75	25	957,494	1,251,483	970,154
				100%	4,813,465	6,291,329	4,877,106
			Velpar 2WDL cost		4,423,287	5,781,414	4,481,770
			Difference in cost from change		390,177	509,978	395,336

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 18. Alternative herbicides to Poast 1.5EC and Select 2EC - Application details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl [a]	Appl method	Percent control [b]
Clethodim	Select Max 1E	Foxtail, Waltergrass, annual/perennial grasses	1	Jan- Sept	4.62fl. oz/ac	Ground/Air	> 80%
Imazamox	Raptor 1E		1	March- Sept	4.99 fl. oz/ac	Ground/Air	60-80%

[a] Most use rates based on 2005 pesticide use report data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Poast 1.5 EC.
[c] Restrictions in water protection areas.

Table 19. Cost of Poast 1.5 EC and Prism and replacement cost of alternative herbicides to Poast 1.5EC and Select 2EC

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl method	Total material cost/ac	Total material & appl. cost/ac [a]
Clethodim	Select Max 1E	172.91	Gal	4.62	Ground/Air	6.24	15.24
Imazamox	Raptor 1E	800.00	Gal	4.99	Ground/Air	31.20	40.20

[a] Total material cost per treated acre plus application cost of $9.00 per acre times number of applications.

Table 20. Replacement cost of alternative scenarios for Poast 1.5EC

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Poast 1.5EC replacement acreage	Replacement cost[a] 2005	2006	2007
Foxtail, Waltergrass, annual/perennial grasses	Alternative 1	Select Max 1E	30.48	70	1,006,429	637,991	427,946
	Alternative 2	Raptor 1E	40.20	30	568,913	360,643	241,909
				100%	1,575,342	998,634	669,885
			Cost of Poast 1.5EC		4,020,127	2,548,421	1,709,408
			Difference in cost from change		(2,444,785)	(1,549,787)	(1,039,553)

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 21. Replacement cost of alternative scenarios for Select 2EC

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Select 2EC replacement acreage	Replacement cost[a] 2005	2006	2007
Foxtail, Waltergrass, annual/perennial grasses	Alternative 1	Select Max 1E	30.48	70	1,863,893	2,315,725	1,309,122
	Alternative 2	Raptor 1E	40.20	30	1,053,618	1,309,029	740,018
				100%	2,917,510	3,624,754	2,049,140
			Select 2EC cost		4,570,659	5,678,648	3,210,243
			Difference in cost from change[b]		(1,653,148)	(2,053,894)	(1,161,104)

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 22. Alternative herbicidexs to Eptam 7-E - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl [a]	Appl method	Percent control [b]
EPTC	Eptam 20G	Annual grasses	2.5	March-Sept.	18.75 lb/ac	Ground/Air	60-80%
Norflurazone	Solicam 80DF	Nutsedge sp.	1.5	March-Sept.	2.81 lb/ac	Ground/Air	60-80%
Halosulfuron	Sandea 75WDG		1	May-Aug	0.05 lb/ac	Ground	60-75%

[a] Most use rates based on 2005 pesticide use report data, i.e., active ingredient/ac modified to formulated amount/ac.

[b] Compared to Eptam 8E

Table 23. Cost of Eptam 7-E and replacement costs of alternative herbicides to Eptam 7-E

Chemical name	Trade name	Cost	Unit	Ave. Rate/ac	Appl method [a,b]	Total material cost/ac	Total material & appl. cost/ac [a,b]
EPTC	Eptam 20G	2.72	lb	18.75	Ground/Air	51.00	73.50
Norflurazone	Solicam 80DF	29.97	lb	2.81	Ground/Air	84.29	97.79
Halosulfuron	Sandea 75WDG	778.40	lb	0.05	Ground	40.48	49.48

[a] Application cost of ground/air speed sprayer is $10.50/ac.

[b] Application cost of ground speed sprayer is $9.00/ac.

Table 24. Replacement cost of alternative scenarios for Eptam 7-E

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Eptam 8-E replacement acreage	Replacement cost[a] 2005	2006	2007
Annual grasses	Alternative 1	Eptam 20G	73.50	25	641,091	367,010	492,468
Nutsedge sp.	Alternative 2	Solicam 80DF	97.79	50	1,705,923	976,603	1,310,443
	Alternative 3	Sandea 75WDG	49.48	25	431,553	247,054	331,507
				100%	2,778,567	1,590,668	2,134,419
			Eptan 8-E cost		2,388.671	1,367,461	1,834,911
			Difference in cost from change		389,896	223,207	299,507

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative

Almond

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California is the only state in the United States to produce almonds commercially. Over the last five years, California has produced, on average, 67% of the world's almonds. The state's 6,000 almond growers farmed about 730,000 acres in the 2006 growing season. Out of these 730,000 acres, 585,000 are bearing trees and 145,000 are non-bearing. In 2006, almonds in California were worth more than $2.2 billion. The almond industry, located primarily in the San Joaquin and Sacramento valleys, faces a wide variety of pests and diseases across a broad geographical area.

Losses from Weeds

Weeds can cause a multitude of problems in almond orchards by reducing the growth of young trees because they compete for water, nutrients and space. Weeds can also contribute to vertebrate, invertebrate and other pest problems. There are a variety of chemical and cultural control practices that can be employed against weeds.
Non-cultivation of orchard soils with herbicide-treated strips down tree rows is common. Orchard floor management is of particular importance to an almond grower because the crop is picked up off the soil surface after being knocked from the trees and swept into windrows. Whether an orchard is tilled, non-tilled, herbicide-treated, or cover-cropped, a primary consideration when performing any cultural operation during the year must be to ensure that the orchard floor is in the best possible condition for harvesting. Almonds begin blooming in mid-February before the danger of frost has passed. Bare and moist ground absorbs more heat and can reduce the threat of frost damage. Close mowing or herbicide treatment are often performed for early season frost protection.

Most orchards are no-till, requiring the use of herbicides and/or mowing to control weeds. Pre-emergent herbicides are generally used only in the tree row. This reduces the total amount of herbicides and prevents the surface roots in the tree row from being damaged by cultivation equipment. By treating the tree row only, 25% to 33% of the total acreage is treated. Pre-emergence, post-emergence, or combinations of pre- and post-emergent herbicides are often used between tree rows.

Losses from Insects and Mites

Numerous insect and mite species injure almond trees and impact nut production (Flint 2002). Several species directly attack the nut. Over the last decade, the navel orangeworm (NOW), *Amyelois transitella*, has been the most important insect pest directly attacking the almond within its shell (Connell 1999). It cannot be managed by insecticides alone and requires the integration of cultural techniques (i.e., mummy sanitation) and careful timing of insecticidal sprays and harvesting. Hard shell varieties are less susceptible to nut damage than soft shell varieties because they can better limit the ability of the NOW larva to enter the shell to feed. Also of significant importance is the peach twig borer (PTB), *Anarsia lineatella*. Like NOW, it also directly feeds on almond nutmeats. Additionally, its injury to almond facilitates infestation by NOW. The pavement ant, *Tetramorium caespitum*, and southern fire ant, *Solenopsis xyloni*, attack fallen almonds as they lay on the ground prior to collection for processing. They are significant problems in the central and southern areas of the San Joaquin Valley and may completely hollow-out nutmeats leaving only the pellicle. Levels of injury are directly related to the amount of time that the almonds lay on the soil surface. Insecticides are the only tool for ant control. In some years, the leaffooted bug, *Leptoglossus clypealis*, can be a severe problem when it feeds on the nut prior to shell hardening and causes the nut to wither and die within the shell or by causing the nut to drop from the tree. Feeding after shell hardening results in unwanted black spots on the nut or wrinkled kernels. Only chemical controls are effective in stopping this insect.

Indirect pests that feed on the non-marketable parts of the plant (e.g., leaves, branches, roots) can reduce yields by removing sap containing needed photosynthates and nutrients needed to fully form almond nuts. These pests include the web spinning mites: Pacific spider mite, *Tetranychus pacificus*, twospotted spider mite, *Tetranychus urticae*, and strawberry spider mite, *Tetranychus turkestani*, that are commonly found on leaves where they feed by inserting their stylets into the tissues. When their densities are high enough, the trees may lose their leaves, which can lead to sunburn and interfere with harvest. Predatory mites are important to the effective management of spider mites (Flint 2002). However, when predators fail to suppress the spider mites for various reasons, miticides are applied to control spider mite populations. Some miticides are soft on predator mites (e.g., propargite, fenbutatin-oxide, clofentezine) and natural biological controls are not completely lost following treatment. A relatively sessile pest found on almonds is San Jose scale, Diaspidiotus perniciosus, which feeds on twigs and branches. When numbers are high, infested branches and twigs stop growing and fruit spurs will be lost. Several natural enemies attack San Jose scale and can keep infestations in check. However, if scale densities become high the natural enemies will be unable to prevent plant damage and an insecticide treatment will be required. The optimal time to control this species is during the dormant period or early season.

VOC Products Used in Almond Crop Production

Numerous compounds are available for weed, insect, and mite control in almonds. Some of these products produce vast quantities of volatile organic compounds (VOC) that reduce air quality in California. This problem results because these organic compounds have high vapor pressures under normal conditions, and they vaporize and enter the atmosphere, thereby causing human health problems and contributing to global warming. To reduce potential problems caused by VOC producing pesticides, the California Department of Pesticide Regulation (DPR) proposes to regulate products with emission potentials (EP) of greater than 20%. Almonds are the third largest VOC contributor of all agricultural commodities. Almonds contributed over 300,000 lbs of VOC producing materials from emulsifiable concentrate formulations in 2005. Discussed here are all active ingredients with a 20% or greater EP that contribute about 1% or more of the total VOC produced on almonds, which include the herbicides oxyfluorfen, pendimethalin, oryzalin, and glyphosate**;** the insecticide chlorpyrifos, and the miticide abamectin. These VOC producing pesticides and alternative non-VOC producing pesticides or formulations are discussed below with regard to pest control activity and IPM potential.

Herbicides

Oxyfluorfen – Oxyfluorfen, sold as Goal 2XL and several other trade names, has an emission potential (EP) of 39 (Table 1). Goal 2XL is used here to generically represent all formulations of oxyfluorfen that exceed an EP of greater than 20%. It is applied following harvest up to February 15. Oxyfluorfen is a selective broadleaf herbicide effective as a pre- and post-emergent material (Table 2). Goal 2XL was applied to 621,801, 660,517, and 591,142 acres of almonds in 2005, 2006, and 2007, respectively. It is particularly useful when combined with glyphosate to increase efficacy on various broadleaf weed species and to prevent broadleaf species shifts with repeated use of only oxyfluorfen. Oxyfluorfen is often used because of its effectiveness on malva. An alternative to the Goal 2XL formulation is a relatively new formulation of oxyfluorfen, GoalTender (Table 1), which has an EP of 5. The solvents in the Goal 2XL formulation may increase activity compared to the GoalTender formulation, although this has not been thoroughly evaluated in almonds. Another alternative could be simazine, which has an EP of 1 when formulated as a wettable powder (Princep Caliber 90) or an EP of 9 when formulated as a liquid (Princep 4L) (Table 1). Simazine controls many of the weeds controlled by oxyfluorfen, but does not control malva. Simazine is considered to be a ground water contaminant and requires a use permit within Ground Water Protection Areas. The elimination of Goal 2XL and replacement with low VOC alternatives of Goal Tender and Princep Caliber 90 would increase costs to almond growers by $71,215, $75,649 and $67,703 in 2005, 2006 and 2007, respectively or about $0.11 per acre (Table 6). Thus the elimination of Goal 2XL would have little or no adverse financial impact on almond growers.

Pendimethalin – Pendimethalin, formulated as Prowl 3.3 EC (Table 1), has an EP of 42. Prowl 3.3 EC is used here to generically represent all formulations of pendimethalin that exceed an EP of greater than 20%. Pendimethalin is applied as a pre-emergent herbicide by ground one time per season at the rate of 2.0 lb per acre. Prowl 3.3 EC was applied to 35,900, 21,173, and 8,114 acres of almonds in 2005, 2006, and 2007, respectively. It is effective on annual grasses and some broadleaf weeds (Table 2). An alternative to Prowl 3.3 EC is Prowl H_2O (Table 1). Prowl H_2O has recently been registered in California for use in almonds and other crops. Prowl H_2O is a water-based flowable formulation, and thus has a lower EP than Prowl 3.3 EC, which is a petroleum solvent-based formulation. The solvents in Prowl 3.3 EC may increase the activity of other herbicides in a tank mix. While Prowl 3.3 EC is registered for non-bearing almonds, Prowl H_2O also has a supplemental label for use in bearing almonds (supplemental label expired 3 Dec. 2008). Another alternative to pendimethalin could be simazine (Table 1), which has an EP of 1 when formulated as a wettable powder (Princep Caliber 90) or an EP of 9 when formulated as a liquid (Princep 4L). Simazine controls many of the weeds controlled by pendimethalin, but does not control several important grasses which are controlled by pendimethalin, including junglerice, crabgrass, and sandbur. Simazine is considered to be a ground water contaminant and requires a use permit within Ground Water Protection Areas. The cost of Prowl 3.3 EC per acre is $15.51 (Table 8). The new formulation of Prowl H^2O would cost $15.81 or $0.30 more per acre. Growers currently using Prowl 3.3 EC would likely continue to use the new formulation, however, some growers will use Princep Caliber 90 due to the lower cost. The elimination of Prowl 3.3 EC and the replacement with Prowl H_2O and Princep Caliber 90 would have increased grower cost only $712, $420 and $161 in 2005, 2006 and 2007, respectively with an increase to the growers of less than $0.05 per acre (Table 9). Thus, the elimination of Prowl 3.3 EC would have little or no adverse financial impact on almond growers.

Oryzalin – The liquid formulation of oryzalin, Surflan A.S. (Table 1), has an EP of 39. Surflan A.S. is used here to generically represent all formulations of oryzalin that exceed an EP of greater than 20%. Oryzalin is applied at 2 to 4 lb per acre as a pre-emergent herbicide in the tree strip by ground, one time per season. This product is a pre-emergence selective herbicide most effective on annual grass species and numerous broadleaf annuals (Table 2). Surflan A.S. was applied to 17,278, 18,111, and 11,262 acres of almonds in 2005, 2006, and 2007, respectively. Surflan is very safe for young or newly planted trees and on sandy or sandy loam soils. It is used to maintain control in strips down the row. It is often used in combination with other pre-emergence herbicides. An alternative for use in almonds is a dry flowable formulation, Surflan Dry Flowable (Table 1), with an EP of 1. Another alternative to oryzalin could be simazine (Table 1), which has an EP of 1 when formulated as a wettable powder (Princep Caliber 90) or an EP of 9 when formulated as a liquid (Princep 4L). Simazine controls many of the weeds controlled by oryzalin, but does not control several important grasses or field bindweed seedlings, which are controlled by oryzalin. Simazine is considered to be a ground water contaminant and requires a use permit within Ground Water Protection Areas. Oryzalin (Surflan A.S.) is used on less than 3% of the almond acres (Table 2). The new dry flowable formulation of oryzalin (Surflan Dry Flowable) controls the same spectrum of weeds and is the most likely product to replace Surflan A.S. However, the cost of the Surflan Dry Flowable is $7.03 more expensive per acre than Surflan A.S. Although simazine (Princep Caliber 90) is less efficacious, some growers will change to this herbicide due to the lower cost. It is estimated that replacement cost per year for oryzalin (Surflan A.S.) will be around $100,000 per year (Table 12). The elimination of Surflan A.S. and the replacement with Surflan Dry Flowable and Princep Caliber 90 would have increased grower cost $106,473, $111,606 and $69,426 in 2005, 2006 and 2007, respectively with an increase to the growers $6.16 per acre (Table 12). Thus the elimination of Surflan A.S. would have an adverse financial impact on almond growers.

Glyphosate – Glyphosate is sold under many trade names (Table 1). A few of these brands have an EP of 39 (i.e., Gly-Flo, Glyfos, and Gly-4 herbicide). Some glyphosate products have EP values near 6 (i.e., Roundup Weathermax, 4.80; Glyphomate 41, 5.71; and Touchdown, 5.71). Three products have an EP of zero (Glyphos, Roundup Original, and Roundup Ultramax). Glyphosate is the most frequently used herbicide in almonds, and is applied during the dormant, pre- and/or post-bloom by ground. Glyphosate, with EP values 20 or greater, was applied to 50,042 acres, 3,832 acres and 9,898 acres of almonds in 2005, 2006, and 2007, respectively. It is often applied at low rates several times during the season. This accounts for the fact that use data indicate this material is applied to >100% of the acreage. Annual use rate of glyphosate averages 0.75 lb. a.i. per acre. Glyphosate is a nonselective, systemic herbicide, used for a broad range of weed species (Table 2). It is effective at anytime on emerged weeds, but activity is slower in lower temperatures. Glyphosate is the best material available for most perennial weeds. It is not effective on some broadleaf weeds at older growth stages (malva and filaree). Glufosinate (Rely) is often considered an alternative to glyphosate in terms of weed control, but the EP of Rely is also 39, and thus not a viable alternative if reducing VOC's is the goal. The only effective alternative would be to use formulations with low EPs. Glyphosate is used extensively in almonds, and will likely continue to be used. The replacement cost of using formulations of glyphosate having EP less than 20 would have increased grower cost $50,042, $3,756 and $9,701 in 2005, 2006 and 2007, respectively with an increase to the growers $1.00 per acre (Table 15). Glyphosate prices have fluctuated widely over the past few years, yet growers continue to use this broadspectrum herbicide. The slightly higher replacement costs will not influence a grower's decision on the use of this product. Thus, the elimination of Gly-Flo, Glyfos, and Gly-4 would not have an adverse financial impact on almond growers.

Insecticides and Miticides

Chlorpyrifos – Lorsban 4E and Nufos 4E are emulsifiable concentrates with EP values greater than 39 (Table 1). Lorban 4E and Nufos 4E are used here to generically represent all formulations of chlorpyrifos that exceed an EP of greater than 20%. Lorsban 4E and Nufos 4E were applied to 154,376, 293,082, and 226,918 acres of almonds in 2005, 2006, and 2007, respectively (Table 2). This contributed 319,300, 635,700, and 487,800 lbs of VOC emissions into the atmosphere in 2005, 2006, and 2007, respectively (Table 3). A new product is now available named Lorsban Advanced (3.76 EW), which was formulated as a chlorpyrifos alternative with very low VOC emissions (Table 16). It is the first chlorpyrifos product to achieve a low-odor, low-VOC in a water-based formulation. It can be directly substituted for Lorsban 4E or Nufos 4E. Lorsban 75WG is also registered on almonds and has an EP value 4 (Table 16). Lorsban 75WG can substitute for Lorsban 4E for most uses with similar efficacy. Lorsban 4E or 75WG may be applied as an in-season foliar application as well as a dormant/delayed-dormant application. Chlorpyrifos is used to manage numerous pests of almonds including navel orangeworm (NOW), peach twig borer (PTB), oriental fruit moth (OFM), *Grapholitha molesta*, European fruit lecanium, *Parthenolecanium corni*, tree borers (i.e., prune limb borer, *Bondia comonana*, American plum borer, *Euzophera semifuneralis*), ants (i.e., pavement ant, southern fire ant), leaffooted bug, and San Jose scale (Table 2). A ranking of effectiveness and value of various conventional insecticides recommended for use in pest management programs for almond pests by the UC IPM Pest Management Guidelines (2009) places chlorpyrifos as #1 for ants, #2 for leaffooted bug, OFM, and tree borers, #3 for San Jose scale (spring applications) and stink bugs, and #4 for NOW. Efficacious alternatives to Lorsban 4E exist for most uses. However, the alternatives may increase production costs.

Navel orangeworm is the major insect pest of concern on almonds and is managed via a combination of cultivar selection, cultural controls, harvest timing, and insecticide applications (Pickel et al. 2004). Alternatives for Lorsban 4E for in-season control of NOW include: Lorsban Advanced, azinphosmethyl (Guthion 50WP), phosmet (Imidan 70WP), and bifenthrin (Brigade 10WP) with EP values of 2, 2, 1 and 2, respectively (Table 16). It should be noted that chlorpyrifos (Lorsban Advanced) may contribute to the outbreak of spider mites (Metcalfe et al. 2002). The registration of azinphosmethyl is expected to be cancelled by 2010, but Brigade 10WP was recently registered for use on almonds. Brigade 10WP provides superior control of NOW compared to Lorsban 4E and other alternatives. Brigade 10WP also provides suppression of spider mite populations (Metcalfe et al. 2002). Additionally, the insect growth regulator methoxyfenozide (Intrepid 2F, EP value 5) provides efficacious control of moderate to low NOW populations. Alternatives for Lorsban 4E for PTB control for dormant/delayed-dormant applications include: horticultural oil plus diflubenzuron (Dimilin 2L, EP value 6), diazinon (Diazinon 50WP, EP value 5), methidathion (Supracide 25W, EP value 1), and Imidan 70WP in addition to Lorsban 75WG (Table 16). Alternatives for Lorsban 4E for in-season control of PTB include: Lorsban Advanced, *Bacillus thuringiensis* ssp. *kurstaki* (Dipel DF, EP value 2), Dimilin 2L and Intrepid 2F during bloom and spinosad (Success 2SC, EP value 6) and Intrepid 2F for spring applications. Alternatives for Lorsban 4E for in-season control of OFM include Success 2SC and Imidan 70WP. Alternatives for Lorsban 4E for tree borers (i.e., prune limb borer, American plum borer) include: Lorsban Advanced and Lorsban 75WG (Table 16). Alternatives for Lorsban 4E for San Jose scale control for dormant/delayed-dormant applications include: horticultural oil plus pyriproxyfen (Seize 35WP, EP value 2), Diazinon 50WP and Supracide 25W in addition to Lorsban Advanced or Lorsban 75WG (Table 16). Note that Lorsban Advanced cannot be applied as a dormant/delayed-dormant treatment in the counties of Butte, Colusa, Glenn, Solano, Sutter, Tehama, Yolo, and Yuba. Alternatives for Lorsban 4E for in-season San Jose scale control include: buprofezin (Applaud 70WP, EP value 2), Seize 35WP, and Supracide 25WP in addition to Lorsban 75WG. Alternatives for Lorsban 4E for ant control include: abamectin (Clinch Ant Bait, EP value of 4) and pyriproxyfen (Esteem Ant Bait, EP value 4) in addition to Lorsban Advanced or Lorsban 75WG (Table 16).

Pesticide cost is one of the prime considerations that growers and consultants make when choosing products for pest suppression. The total cost (product + application costs) of a Lorsban 4E treatment is $32.55 per acre (Table 17). Costs for alternatives to Lorsban 4E range from $14.83 per acre (Applaud 70 WP) to $105.65 per acre (Assail 30SG) with 12 out of 17 available products costing more to use than Lorsban 4E. One may assume that if growers are satisfied with the control they obtain with Lorsban 4E, most growers will probably substitute Lorsban Advanced to achieve similar control with reduced VOC production. However, this action will cost them an additional $9.31 per acre in product costs. Given all the possible registered alternatives in California to Lorsban 4E usage in 2005, 2006, and 2007, we estimated that a complete substitution for Lorsban 4E with safer, low VOC products would have been $1,662,284, $3,155,837, and $2,443,399 in additional costs, based on treated acreages in 2005, 2006, and 2007, respectively (Table 18). This would be an increase of $10.77 per acre. In some locations (Butte, Colusa, Glenn, Solano, Sutter, Tehama, Yolo, and Yuba Counties), it is prohibited to use Lorsban Advanced as a dormant/delayed-dormant application for pests such as San Jose scale. In these counties, products such as Lorsban 75WG may be substituted at $58.25 per acre if chlorpyrifos is desired as the active ingredient. If not, the products Diazinon 50WP and Supracide 25 at $44.04 and $96.00 per acre, respectively, may be applied.

Abamectin – Agri-Mek 0.15EC (EP value 55) is a highly effective miticide (Table 1). It is used mainly for Pacific, twospotted, and strawberry spider mites (Table 2). Agri-Mek 0.15EC is used here to generically represent all formulations of abamectin that exceed an EP of greater than 20%. Agri-Mek 0.15EC was applied to 285,937, 375,630, and 430,813 acres of almonds in 2005, 2006, and 2007, respectively (Table 2). This is a larger area than that which received chlorpyrifos treatments during the same time period. Pounds of VOC emissions produced by applications of Agri-Mek 0.15EC equaled 95,100, 122,100, and 128,000 lbs in 2005, 2006, and 2007, respectively (Table 3). This quantity is less than that produced from chlorpyrifos treatments during the same time period.

A ranking of effectiveness and value of 12 miticides recommended for control of webspinning spider mites on almond by the UC IPM Pest Management Guidelines (2009) places Agri-Mek 0.15EC as #2 with bifenazate (Acramite 50WS) being #1. Agri-Mek 0.15EC is a prophylactic miticide that is applied early in the season to young almond foliage to achieve adequate penetration into the leaves. The material is less effective when applied to mature foliage because of reduced penetration into the leaves. Alternatives to Agri-Mek 0.15EC include: propargite (Omite 30WP, EP value 2), acequinocyl (Kanemite 15SC, unknown EP value) and bifenazate (Acramite 50WS, EP value 2) (Table 19). These miticides are effective against all motile stages and are relatively fast acting. Other miticide alternatives include: hexythiazox (Savey DF, EP value 1), clofentezine (Apollo SC, EP value 9), fenbutatin-oxide (Vendex 50WP, EP value 2) and spirodiclofen (Envidor 2SC, EP value unknown). These miticides are ovicidal or active against immature mites. They tend to be slow to show effects because of delayed mortality. However, these miticides are effective, but should be applied when mite populations are first observed.

The cost (product + application expense) of treating an acre of almonds with Agri-Mek 0.15EC is $70.00 (Table 20). Available low VOC-producing alternatives to Agri-Mek 0.15EC fall into three groups: inexpensive, moderately priced, and expensive. The inexpensive products are Kanemite 15SC and Acramite 50WS and cost less than $14 per application per acre (Table 20). Acramite 50WS is the most highly recommended by the UC IPM Pest Management Guidelines (2009). Moderately priced and less expensive than an Agri-Mek 0.15EC treatment is Apollo SC at $58.33 per application per acre (Table 20). The expensive alternatives are greater than $120 per acre and include Omite 30WP, Savey DF, and Vendex 50WP (Table 20). Although Acramite 50WS is highly recommended, it would theoretically only be used 10% of the time when spider mites were targeted for control with miticides (Table 21). The most common product that would theoretically be used to replace Agri-Mek 0.15EC would be Omite 30WP and it would be used on 30% of the acreage needing treatment. Total differences in the cost to change from using Agri-Mek 0.15EC to the other available products would have been $10,402,288, $13,665,288, and $15,672,826 in 2005, 2006, and 2007, respectively (Table 21) or an increase in cost of about $36.38 per acre. Of significant interest is the finding that the costs to switch away from using Agri-Mek 0.15EC for spider mites would be much greater (i.e., 6.2-, 4.3-, and 6.4-fold in 2005, 2006, and 2007, respectively) than those costs for replacing Lorsban 4E use for other pests.

Conclusions

Analysis reveals that compounds are available that can be used as effective substitutes for the most VOC-producing herbicides, insecticides, and miticides used on California almonds. With the substitutions, similar levels of efficacy are expected. However, the annual costs of replacing these compounds is quite variable in a given year, ranging from as little as $420 for the herbicide Prowl 3.3 EC to greater than $8 million for the herbicide Gly-Flo. The herbicides will be generally less expensive to replace than the insecticide Lorsban 4E and the miticide Agri-Mek 0.15EC, which ranged from $1.6 to 3.1 million and $10.4 to 15.6 million, respectively, in replacement costs. Additionally, in the future we may see pesticide manufacturers responding to the challenge of creating effective products with reduced VOC output as demonstrated by the development of Lorsban Advanced to replace Lorsban 4E.

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Tables

Table 1. VOC Producing Herbicides, Insecticides, Miticides, and Alternatives

VOC Producers and Alternatives	Materials	Detail Table reference	Yield loss (%)	Quality change (high, medium, low, none)
	Herbicides			
VOC Producing Herbicide	**Oxyfluorfen (Goal 2XL)**	**2.1**	**0%**	**none**
Alternative 1	Oxyfluorfen (GoalTender)	4.1	0%	none
Alternative 2	Simazine (Princep Caliber 90)	4.2	0%	none
VOC Producing Herbicide	**Pendimethalin (Prowl 3.3)**	**2.2**	**0%**	**none**
Alternative 1	Pendimethalin (Prowl H_2O)	7.1	0%	none
Alternative 2	Simazine (Princep Caliber 90)	7.2	0%	none
VOC Producing Herbicide	**Oryzalin (Surflan A.S.)**	**2.3**	**0%**	**none**
Alternative 1	Oryzalin (Surflan Dry Flowable)	10.1	0%	none
Alternative 2	Simazine (Princep Caliber 90)	10.2	0%	none
VOC Producing Herbicide	**Glyphosate (Gly-Flo, Glyfos, Gly-4 herbicide)**	**2.4**	**0%**	**none**
Alternative 1	Glyphosate (Glyphos, Roundup Original, Roundup Ultramax, Roundup Weathermax, Glyphomate 41, Touchdown)	13	0%	none
	Insecticides			
VOC Producing Insecticide	**Chlorpyrifos (Lorsban 4E or Nufos 4E)**	2.5	0%	none
Alternative 1	Chlorpyrifos (Lorsban Advanced)	16.1	0%	none
Alternative 2	Chlorpyrifos (Lorsban 75WG)	16.2	0%	none
Alternative 3	Phosmet (Imidan 70WP)	16.3	0%	none
Alternative 4	Bifenthrin (Brigade 10WP)	16.4	0%	none
Alternative 5	Methoxyfenozide (Intrepid 2F)	16.5	0%	none
Alternative 6	Diflubenzuron (Dimilin 2L)	16.6	0%	none
Alternative 7	Diazinon (Diazinon 50WP)	16.7	0%	none
Alternative 8	Methidathion (Supracide 25W)	16.8	0%	none
Alternative 9	*Bacillus thuringiensis* ssp. *kurstaki* (Dipel DF)	16.9	0%	none
Alternative 10	Spinosad (Success 2SC)	16.10	0%	none
Alternative 11	Pyriproxyfen (Seize 35WP)	16.11	0%	none
Alternative 12	Buprofezin (Applaud 70WP)	16.12	0%	none
Alternative 13	Abamectin (Clinch Ant Bait)	16.13	0%	none
Alternative 14	Pyriproxyfen (Esteem Ant Bait)	16.14	0%	none
Alternative 15	Cyfluthrin (Renounce 20WP)	16.15	0%	none
Alternative 16	Acetamiprid (Assail 30SG)	16.16	0%	none
Alternative 17	Spinetoram (Delegate 25 WG)	16.17	0%	none

	Miticides			
VOC Producing Pesticide	**Abamectin (Agri-Mek 0.15EC)**	2.6	0%	none
Alternative 1	Propargite (Omite 30WP)	19.1	0%	none
Alternative 2	Acequinocyl (Kanemite 15SC)	19.2	0%	none
Alternative 3	Bifenazate (Acramite 50WS)	19.3	0%	none
Alternative 4	Hexythiazox (Savey 50 DF)	19.4	0%	none
Alternative 5	Clofentezine (Apollo SC)	19.5	0%	none
Alternative 6	Fenbutatin-oxide (Vendex 50WP)	19.6	0%	none

Table 2. VOC Producing Pesticides - Application Details

Chemical name	Trade name	Pest(s) controlled	No. acres treated[a] 2005	2006	2007	Months of appls.	Rate formulated / acre/ application[b,c]	Percent control
			Herbicides					
1) Oxyfluorfen	Goal 2XL	Broadleaf weeds	621,801	660,517	591,142	Nov. – Feb.	18 oz/ac	80
2) Pendimethalin	Prowl 3.3 EC	Broadleaf and grass weeds	35,900	21,173	8,114	Nov. – Feb.	7.8 oz/ac	100
3) Oryzalin	Surflan A.S.	Broadleaf and grass weeds	17,278	18,111	11,266	Nov. – Feb.	55 oz/ac	80
4) Glyphosate	Gly-Flo, Glyfos, Gly-4 herbicide	Broadleaf and grass weeds	50,042	3,832	9,898	Year-round	33 oz/ac	95
			Insecticide					
5) Chlorpyrifos	Lorsban 4E	Navel orangeworm, peach twig borer, oriental fruit moth, European fruit lecanium, tree borers, ants, leaffooted bug, San Jose scale	154,376	293,082	226,918	Nov. – Sept.	3.68 pt/ac	90
			Miticide					
6) Abamectin	Agri-Mek 0.15EC	Web spinning mites	285,937	375,630	430,813	Mar.- Aug.	7.8 oz/ac	100

[a] Use rates (acres treated with 20+ EP value) from 2005 - 2007 pesticide use report data (California Department of Pesticide Regulation, 2005 to 2007).
[b] Formulated amount of herbicides based on 2006 pesticide use report data i.e. active ingredient/ac modified to formulated amount/ac.
[c] Formulated amount of insecticide and miticide based on 2005 pesticide use report data i.e. active ingredient/ac modified to formulated amount/ac.

Table 3. Amount (lbs) and percent of total VOC emission produced by active ingredients for 2005 through 2007 in almond

		2005		2006		2007	
Chemical name	**Trade name**	**Amount[a]**	**Percent**	**Amount[a]**	**Percent**	**Amount[a]**	**Percent**
			Herbicides				
Oxyfluorfen	Goal 2XL	396.7	24.6%	526.5	22.9%	550.5	24.5%
Pendimethalin	Prowl 3.3 EC	59.4	3.7%	34.9	1.5%	19.7	0.9%
Oryzalin	Surflan A.S.	36.9	2.3%	42.0	1.8%	30.1	1.3%
Glyphosate	Gly-Flo, Glyfos, Gly-4	61.3	3.8%	4.5	0.2%	11.4	0.5%
			Insecticide				
Chlorpyrifos	Lorsban 4E	319.3	19.8%	635.7	27.6%	487.8	21.7%
			Miticide				
Abamectin	Agri-Mek 0.15EC	95.1	5.9%	122.1	5.3%	128.0	5.7%

[a] Amount times 1000 pounds from 2005 to 2007 pesticide use report data (California Department of Pesticide Regulation, 2005 to 2007).

Table 4. Alternatives to Goal 2XL Application Detail

Alternative	**Trade Name**	**Pest(s) controlled**	**Number of Applications**	**Months of application(s)**	**Rate Formulated Product/Acre/ Application [a]**	**Predominate Application Method**	**% control [b]**
Alternative 1	GoalTender	Broadleaf weeds	1	Nov. – Feb.	9 oz/ac	Ground	80
Alternative 2	Princep Caliber 90	Broadleaf and grass weeds	1	Nov. – Feb.	0.64 lbs/ac	Ground	70

[a] Most use rates based on 2006 PUR data,i.e. active ingredient/ac modified to formulated amount/ac (California Department of Pesticide Regulation, 2005 to 2007).

[b] Compared to Goal 2XL

Table 5. Cost of Goal 2XL and replacement cost of alternative insecticides for Goal 2XL

Chemical name	Trade name	Cost	Unit	Ave. Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac [a]
Oxyfluorfen	GoalTender	2.19	fl.oz	9.00	Ground	6.50	15.50
Simazine	Princep Caliber 90	5.08	lb	0.64	Ground	1.07	10.07

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 6. Replacement cost of alternative scenarios for Goal 2XL

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Goal 2XL replacement acreage	Replacement cost[a] 2005	2006	2007
Broadleaf weeds	Alternative 1	GoalTender	15.50	95	9,158,556	9,728,807	8,706,981
Broadleaf and grass weeds	Alternative 2	Princep Caliber 90	10.07	5	313,167	332,666	297,726
			Total	100%	9,471,723	10,061,473	9,004,707
				Cost of Goal 2XL	9,400,508	9,985,824	8 937 004
			Difference in cost from change		71,215	75,649	67,703

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 7. Alternatives to Prowl 3.3 EC Application Detail

Alternative	Trade Name	Pest(s) controlled	Number of Applications	Months of application(s)	Rate Formulated Product/Acre/ Application [a]	Predominate Application Method	% control [b]
Alternative 1	Prowl H_2O	Broadleaf and grass weeds	1	Nov. – Feb.	59 oz/ac	Ground	80
Alternative 2	Princep Caliber 90	Broadleaf and grass weeds	1	Nov. – Feb.	0.64 lbs/ac	Ground	70

[a] Most use rates based on 2006 PUR data,i.e. active ingredient/ac modified to formulated amount/ac (California Department of Pesticide Regulation, 2005 to 2007).
[b] Compared to Prowl 3.3 EC

Table 8. Cost of Prowl 3.3 EC and replacement costs of alternative miticides to Prowl 3.3 EC

Chemical name	Trade name	Cost	Unit	Ave. Rate/ac	Appl method [a]	Total material cost/ac	Total material & appl. cost/ac [a]
Pendimethalin	Prowl H_2O	0.35	fl.oz	59.00	Ground	6.81	15.81
Simazine	Princep Caliber 90	5.08	lb	0.64	Ground	1.07	10.07

[a] Application cost of ground speed sprayer is $9.00/ac.Table 9. Replacement cost of alternative scenarios for Prowl 3.3 EC

Table 9. Replacement cost of alternative scenarios for Prowl 3.3 EC

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Prowl 3.3 EC replacement acreage	Replacement cost[a] 2005	2006	2007
Broadleaf and grass weeds	Alternative 1	Prowl H_2O	15.81	95	539,359	318,091	121,897
Broadleaf and grass weeds	Alternative 2	Princep Caliber 90	10.07	5	18,081	10,663	4,086
				100%	557,440	328,754	125,983
				Cost of Prowl 3.3 EC	556,728	328,335	125,822
			Difference in cost from change		712	420	161

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 10. Alternatives to Surflan A.S. Application Detail

Alternative	Trade Name	Pest(s) controlled	Number of Applications	Months of application(s)	Rate Formulated Product/Acre/ Application [a]	Predominate Application Method	% control [b]
Alternative 1	Surflan Dry Flowable	Broadleaf and grass weeds	1	Nov. – Feb.	2 lbs/ac	Ground	80
Alternative 2	Princep Caliber 90	Broadleaf and grass weeds	1	Nov. – Feb.	0.64 lbs/ac	Ground	70

[a] Most use rates based on 2006 PUR data,i.e. active ingredient/ac modified to formulated amount/ac (California Department of Pesticide Regulation, 2005 to 2007).

[b] Compared to Surflan A.S. 4L

Table 11. Cost of Surflan A.S. and replacement cost of alternative insecticides for Surflan A.S.

Chemical name	Trade name	Cost	Unit	Ave. Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac [a]
Oryzalin	Surflan Dry Flowable	27.69	lb	2.00	Ground	18.28	27.28
Simazine	Princep Caliber 90	5.08	lb	0.64	Ground	1.07	10.07

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 12. Replacement cost of alternative scenarios for Surflan A.S.

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Surflan A.S. 4L replacement acreage	Replacement cost[a] 2005	2006	2007
Broadleaf and grass weeds	Alternative 1	Surflan Dry Flowable	27.28	95	447,706	469,292	291,927
Broadleaf and grass weeds	Alternative 2	Princep Caliber 90	10.07	5	8,702	9,122	5,674
				100%	456,408	478,413	297,601
				Cost of Surflan A.S.	349,935	366,807	228,175
				Difference in cost from change	106,473	111,606	69,426

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 13. Alternatives to Gly-Flo, etc. Application Detail

Alternative	Trade Name	Pest(s) controlled	Number of Applications	Months of application(s)	Rate Formulated Product/Acre/ Application [a]	Predominate Application Method	% control [b]
Alternative 1	Glyphos, Roundup Original, Roundup Ultramax, etc.	Broadleaf and grass weeds	3	Year-round	33 oz/ac	Ground	95

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac (California Dept. of Pesticide Regulation, 2005 to 2007).
[b] Compared to Prowl 3.3 EC

Table 14. Cost of Gly-Flo, etc. and replacement costs of alternative miticides to Gly-Flo, etc.

Chemical name	**Trade name**	**Cost**	**Unit**	**Ave. Rate/ac**	**Appl method [a]**	**Total material cost/ac**	**Total material & appl. cost/ac [a]**
Glyphosate	Glyphos, Roundup Original, Roundup Ultramax, etc.	0.37	fl.oz	33.00	Ground	12.09	39.09

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 15. Replacement cost of alternative scenarios for Gly-Flo, etc.

Target pest(s)	**Alternatives**	**Trade name**	**Cost per acre**	**Percent of Gly-Flo, etc. replacement acreage**	**Replacement cost[a]** 2005	2006	2007
Broadleaf and grass weeds	Alternative 1	Glyphos, Roundup Original, Roundup Ultramax, etc.	39.09	100	704,172	52,849	136,509
				100%	704,172	52,849	136,509
				Cost of Gly-Flo	654,130	49,094	126,808
			Difference in cost from change		50,042	3,756	9,701

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 16. Alternatives to Lorsban 4E Application Detail

Chemical/Generic Name	Trade Name	Pest(s) controlled[e]	Number of Applications	Months of application(s)	Rate Formulated Product/Acre/ Application [a]	Predominate Application Method	% control [b]
Alternative 1	Lorsban Advanced	NOW, PTB, TB, SJS, Ants	1	May-Aug, Nov-Jan	3.8 pt/ac	Ground	100
Alternative 2	Lorsban 75WG	NOW, PTB, TB, SJS, Ants	1	May-Aug, Nov-Jan	2.45 lbs/ac	Ground	100
Alternative 3	Imidan 70WP	NOW, PTB, OFM	1	May-Aug, Nov-Jan	4.9 lbs/ac	Ground	100
Alternative 4	Brigade 10WP	NOW, WSM	1	May-Aug Nov.-Jan	1.2 lbs/ac	Ground	100
Alternative 5	Intrepid 2F [d]	NOW, PTB	1	Feb-Aug	17.3 oz/ac	Ground	100
Alternative 6	Dimilin 2L	PTB	1	May-Aug, Nov-Jan	12 oz/ac	Ground	100
Alternative 7	Diazinon 50WP	PTB, SJS	1	Nov-Jan	3.8 lbs/ac	Ground	100
Alternative 8	Supracide 25W[f]	PTB, SJS	1	May-Aug Nov-Jan	4.0 lbs/ac	Ground	100
Alternative 9	Dipel DF	PTB	1	May-Aug	1.0 lbs/ac	Ground	100
Alternative 10	Success 2SC	PTB, OFM	1	Feb-Aug Nov.-Jan	5.7 oz/ac	Ground	100
Alternative 11	Seize 35WP [g]	SJS, PTB	1	Nov-Jan	5 oz/ac	Ground	100
Alternative 12	Applaud 70WP	SJS	1	May-Aug	2.2 lbs/ac	Ground	100
Alternative 13	Clinch Ant Bait [g]	Ants	1	July-Sept	1 lb/ac	Ground	100
Alternative 14	Esteem Ant Bait [g]	Ants	1	July-Sept	2 lbs/ac	Ground	100
Alternative 15	Renounce 20WP	PTB	1	Nov-Jan	3.5 oz/ac	Ground	100
Alternative 16	Assail 30SG	PTB	1	Nov-Jan	5 oz/ac	Ground	100
Alternative 17	Delegate 25 WG	PTB	1	Nov-Jan	3.2 oz/ac	Ground	100

[a] Most use rates based on 2006 PUR data,i.e. active ingredient/ac modified to formulated amount/ac (California Department of Pesticide Regulation, 2005 to 2007).
[b] Compared to Lorsban 4E
[c] Expected to be canceled by 2010, Brigade 10WP provides superior control of NOW compared to Lorban 4E and other alternatives
[d] Controls low to moderate NOW populations
[e] NOW = Navel orange worm; PTB = Peach twig borer; TB = Twig borers; SJS = San Jose Scale; OFM = Oriental fruit moth; WSM = Web spinning mites
[f] Do not apply more than once/season on foliage. This material may be phytotoxic to some almond varieties when used in season.
[g] Rate based on UC IPM recommendations

Table 17. Cost of Lorsban 4E and replacement cost of alternative insecticides for Lorsban 4E

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac [a]
Chlorpyrifos	Lorsban 4E	6.40	pt	3.68	Ground	23.55	32.55
Chlorpyrifos	Lorsban Advanced	8.65	pt	3.8	Ground	32.86	41.86
Chlorpyrifos	Lorsban 75WG	20.10	lb	2.5	Ground	49.25	58.25
Phosmet	Imidan 70WP	12.39	lb	4.9	Ground	60.71	69.71
Bifenthrin	Brigade 10WP	47.15	lb	1.2	Ground	56.58	65.58
Methoxyfenozide	Intrepid 2F [d]	2.96	fl oz	17.3	Ground	51.21	60.21
Diflubenzuron	Dimilin 2L	2.10	fl oz	12.0	Ground	25.20	34.20
Diazinon	Diazinon 50WP	9.22	lb	3.8	Ground	35.04	44.04
Methidathion	Supracide 25W	9.75	lb	4.0	Ground	39.00	48.00
Bacillus thuringiensis	Dipel DF	15.32	lb	1.0	Ground	15.32	24.32
Spinosad	Success 2SC	7.0	fl oz	5.7	Ground	39.90	48.90
Pyripoxyfen	Seize 35WP [g]	14.49	oz	5.0	Ground	46.37	55.37
Buprofezin	Applaud 70WP	2.65	lb	2.2	Ground	5.83	14.83
Abamectin	Clinch Ant Bait [g]	15.46	lb	1.0	Ground	15.46	24.46
Pyripoxyfen	Esteem Ant Bait [g]	9.49	lb	2.0	Ground	18.93	27.98
Cyfluthrin	Renounce 20WP	3.61	oz	3.5	Ground	12.64	21.64
Acetamiprid	Assail 30SG	19.33	oz	5.0	Ground	96.65	105.65
Spinetoram	Delegate 25WG	9.34	oz	3.2	Ground	28.89	38.89

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 18. Replacement cost of alternative scenarios for Lorsban 4E

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Lorsban 4E replacement acreage	Replacement cost[a] 2005	2006	2007
NOW, PTB, TB, SJS, Ants	Alternative 1	Lorsban Advanced	41.86	84	5,427,680	10,304,420	7,978,171
NOW, PTB, TB, SJS, Ants	Alternative 2	Lorsban 75WG	58.25	1	89,916	170,706	132,168
NOW, PTB, OFM	Alternative 3	Imidan 70WP	69.71	1	107,617	204,310	158,187
NOW, WSM	Alternative 4	Brigade 10WP	65.58	1	101,240	192,203	148,813
NOW, PTB	Alternative 5	Intrepid 2F	60.21	1	92,947	176,459	136,623
PTB	Alternative 6	Dimilin 2L	34.20	1	52,797	100,234	77,606
PTB, SJS	Alternative 7	Diazinon 50WP	44.04	1	67,981	129,062	99,926
PTB, SJS	Alternative 8	Supracide 25W	96.00	1	148,201	281,359	217,841
PTB	Alternative 9	Dipel DF	24.32	1	37,544	71,278	55,186
PTB, OFM	Alternative 10	Success 2SC	48.90	1	75,490	143,317	110,963
SJS, PTB	Alternative 11	Seize 35WP	81.45	1	125,739	238,715	184,825
SJS	Alternative 12	Applaud 70WP	14.83	1	22,894	43,464	33,652
Ants	Alternative 13	Clinch Ant Bait	24.46	1	37,760	71,688	55,504
Ants	Alternative 14	Esteem Ant Bait	27.98	1	43,194	82,004	63,492
PTB	Alternative 15	Renounce 20WP	21.64	1	33,399	63,408	49,094
PTB	Alternative 16	Assail 30SG	105.65	1	163,098	309,641	239,739
PTB	Alternative 17	Delegate 25WG	38.89	1	60,034	113,974	88,244
				100%	6,687,531	12,696,242	9,830,033
				Cost of Lorsban 4E	5,025,248	9,540,405	7,386,635
				Difference in cost from change	1,662,284	3,155,837	2,443,399

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 19. Alternatives to Agri-Mek 0.15EC Application Detail

Alternative	Trade Name	Pest(s) controlled	Number of Applications	Months of application(s)	Rate Formulated Product/Acre/ Application [a]	Predominate Application Method	% control [b]
Alternative 1	Omite 30WP	Web spinning mites	2	March-August	6.3 lb/ac	Ground	100
Alternative 2	Kanemite 15SC	Web spinning mites	1	March-August	31.0 oz/ac	Ground	100
Alternative 3	Acramite 50WS	Web spinning mites	1	March-August	14.7 oz/ac	Ground	100
Alternative 4	Savey 50DF	Web spinning mites	1	March-August	5.2 oz/ac	Ground	100
Alternative 5	Apollo SC	Web spinning mites	1	March-August	6.3 oz/ac	Ground	100
Alternative 6	Vendex 50WP	Web spinning mites	2	March-August	1.9 lbs/ac	Ground	100

[a] Most use rates based on 2006 PUR data,i.e. active ingredient/ac modified to formulated amount/ac (California Department of Pesticide Regulation, 2005 to 2007).

[b] Compared to Agri-Mek 0.15EC

Table 20. Cost of Agri-Mek 1.5EC and replacement costs of alternative miticides to Agri-Mek 0.15EC

Chemical name	Trade name	Cost	Unit	Ave. Rate/ac	Appl method [a]	Total material cost/ac	Total material & appl. cost/ac [a]
VOC	Agri-Mek 0.15EC	7.82	fl oz	7.8	Ground	61.00	70.00
Propargite	Omite 30W	8.23	lb	6.3	Ground	103.7	121.70
Acequinocyl	Kanemite 15SC	2.28	oz	31.0	Ground	5.02	12.02
Bifenazate	Acramite 50WP	5.38	oz	14.7	Ground	4.84	13.84
Hexythiazox	Savey 50WP	20.69	oz	5.2	Ground	103.70	121.70
Clofentezine	Apollo SC	7.83	fl oz	6.3	Ground	49.33	58.33
Fenbutatin-oxide	Vendex 50WP	34.59	lb	1.9	Ground	131.44	149.44

[a] Application cost of ground speed sprayer is $16.00/ac.

Table 21. Replacement cost of alternative scenarios for Agri-Mek 0.15EC

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Agri-Mek 1.5EC replacement acreage	Replacement cost[a]		
					2005	2006	2007
Webspinning mites	Alternative 1	Omite 30WP	121.70	30	10,439,388	13,714,026	15,728,724
Webspinning mites	Alternative 2	Kanemite 15SC	14.02	5	200,385	263,242	301,914
Webspinning mites	Alternative 3	Acramite 50WS	13.84	10	395,794	519,947	596,331
Webspinning mites	Alternative 4	Savey 50DF	116.59	30	10,001,047	13,138,185	15,068,288
Webspinning mites	Alternative 5	Apollo SC	58.33	5	833,921	1,095,506	1,256,445
Webspinning mites	Alternative 6	Vendex 50WP	149.44	20	8,546,199	11,226,980	12,876,311
				100%	30,416,734	39,957,885	45,828,013
				Cost of Agri-Mek 0.15EC	20,014,446	26,292,597	30,155,187
				Difference in cost from change	10,402,288	13,665,288	15,672,826

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Broccoli

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California produces 92% of all commercially grown broccoli in the United States. In 2006, broccoli was produced on 128,500 acres and had a gross value of $599,436,000 (National Agricultural Statistics Service USDA 2006). Broccoli is grown in four regions of California: Central Coast, San Joaquin Valley, South Coast, and Southeastern Desert. California Department of Pesticide Regulation has identified a number of pesticides used on broccoli as contributing volatile organic compounds (VOC) to air quality problems in California. A pesticide with an evaporate potential (EP) of greater than 20% is defined as a VOC. Broccoli is the eighth largest VOC contributor of all agricultural commodities. Broccoli contributed over 268,451 lbs of VOC producing materials from emulsifiable concentration formulations in 2005. The top eight VOC producing pesticides and non-VOC producing alternate pesticides or formulations are discussed with regard to pest control activity and IPM potential.

Herbicides

Bensulide – Prefar 4E, with a default EP value of 39, is widely used in broccoli for control of grasses and broadleaf weeds. Prefar 4E is particularly effective in controlling common purslane (*Portulaca oleracea*) in the summer and is used in the cooler part of the year to provide control of burning nettle (*Urtica urens*) (Table 1). The number of acres treated with Prefar 4E was 10,092 and 8,424 acres for 2005 and 2007, respectively. Prefar 4E contributed 26,900 and 22,300 lbs of VOC for 2005 and 2007 respectively, or about 9% of the non-fumigant VOCs produced in broccoli (Tables 1 and 2).

There are two non-VOC producing alternative herbicides (Dacthal 75W, with an EP value of 2, and Devrinol 50DF with an EP value of 1) for controlling broadleaf and grass weeds in broccoli (Table 3). In a trial conducted in 2000, Prefar 4E provided improved control of burning nettle compared to Dacthal 75W while control of common purslane was similar between these two herbicides. Variances in control of and importance in certain weeds can be seen in different geographies in California, e.g., Imperial Valley versus Salinas. Devrinol 50DF is effective on many of the same weeds as Prefar 4E, but is more effective on shepherd's purse and less effective on common purslane. Devrinol 50DF has more plant back restrictions for lettuce grown in rotation with broccoli and this significantly reduces it use in the coastal counties. Replacing Prefar 4E with Dacthal 75W and Devrinol 50DF would have decreased costs to broccoli growers in the period of 2005 – 2007 by $21,858 to $26,335 or about $2.60 per acre decrease in cost (Table 4). Thus, the elimination of Prefar 4E would have minimal financial impact on broccoli growers. The registrant for Prefar 4E, Gowan Company, is investigating an alternative formulation for bensulide that would have a lower EP values.

Oxyfluorfen – Goal 2XL, with an EP value of 62, is widely used on broccoli and is used in two ways: 1) as a pretransplant application to control broadleaf weeds and 2) as fallow bed treatment prior to planting broccoli. The number of acres treated with Goal 2XL was 12,141 and 8,660 acres for 2005 and 2007, respectively. Goal 2XL contributed 12,600 and 10,600 lbs of VOC for 2005 and 2007, respectively (Tables 1 and 2), or from 4.0 to 4.5% of the non-fumigant VOC produced on broccoli. The low-VOC producing alternative herbicide is GoalTender with an EP value of 4.8. Studies show that the GoalTender, which is a 4F material, is comparable to Goal 2XL as a pretransplant application. As a result, GoalTender can be a direct substitute for Goal 2XL for the pretransplant use in broccoli. Goal 2XL is more effective than GoalTender in fallow bed use as a post-emergence herbicide on larger weeds (i.e., > 3 inches tall); GoalTender can be as effective as a post-emergent application as Goal 2XL only if the weeds are small (i.e., <2 true leaves). When the broccoli has four true leaves, GoalTender has an additional use in broccoli as an over-the-top application to control small weeds, but Goal 2XL is not registered for this use. The formulated amount of the GoalTender to be used as the alternative was based on 2006 PUR data, i.e., active ingredient per acre was modified to the amount of formulated product per acre and was 0.75 pt per acre (Table 5). Replacing Goal 2XL with GoalTender would have increased costs to broccoli growers in the period of 2005 – 2007 by $13,444 to $18,850 or about $1.50 per acre increased cost (Table 6). Thus the elimination of Goal 2XL would have minimal financial impact on broccoli growers.

Trifluralin – Treflan 4EC, 4L, HFP and TR-10 are used in broccoli to control grasses and broadleaf weeds. Treflan 4EC, with an EP value of 39, is particularly effective in controlling grass weeds. The number of acres treated with Treflan 4EC was 10,900 and 8,982 acres for 2005 and 2007, respectively, and contributed 4,100 and 3,400 lbs of VOC for 2005 and 2007, respectively, or about 1.3% of the non-fumigant VOC produced on broccoli (Tables 1 and 2). Treflan 4EC is registered for use on direct seeded and transplanted broccoli. Treflan TR-10 is a lower VOC producing herbicide with an EP value of 3. Although the granular formulation is labeled for use in broccoli, it is rarely used due to difficulties in applying the granular material evenly in the field. Treflan 4EC is an older herbicide and no comparative studies have been conducted of the various formulations. Research on the relative efficacy of Treflan TR-10 and Treflan 4EC is needed before widespread grower adoption would be possible. All formulations are used at the 0.5 to 0.75 lb ai/ac rate for direct seeded broccoli. Dacthal 75W and Devrinol 50DF are alternatives to Treflan 4EC (Table 7). Dacthal 75W and Devrinol 50DF are both effective in controlling a similar spectrum of broadleaf and grass weeds as Treflan 4EC. The formulated amount of Dacthal 75W and Devrinol to be used as the alternatives was based on the 2006 PUR data, i.e., active ingredient per acre was modified to the amount of formulated product per acre and was projected to be used at 4.4 lb/acre for Dacthal 75W and 1.2 lbs/acre for Devrinol 50DF (Table 8). Replacing Treflan 4EC with alternatives would have increased costs to broccoli growers in the period of 2005 – 2007 by $367,365 to $445,813 (Table 8). As opposed to Prefar 4E and Goal 2XL, the elimination of Treflan 4EC would have a major financial impact on broccoli growers. Broccoli growers would face greatly increased costs of about $41.00 per acre if Treflan 4EC, 4L, HFP or TR-10 were eliminated (Table 8).

Insecticides

Chlorpyrifos – Lorsban 4E/Nufos 4E with an EP value of 39 is widely used on broccoli as soil applications for control of root maggots such as cabbage maggot (*Delia radicum*) and seedcorn maggot (*Delia platura*), garden symphylans (*Scutigerella immaculata*), cutworms such as black cutworm (*Agrotis ipsilon*), glassy cutworm (*Crymodes devastator*), granulate cutworm (*Agrotis subterranean*), and variegated cutworm (*Peridroma saucia*), and wireworms (Chaney and Natwick 2007). Lorsban 4E was used on 11,353 acres in 2005 and 10,766 acres in 2007 and contributes approximately 6.8 percent of the VOC emissions among all non-fumigant pesticides used on broccoli (Tables 9 and 10). Chlorpyrifos is also registered as Lorsban Advanced, Lorsban 15G, Nufos 15G, Lorsban 50W and Lorsban 75WG formulations with EP values ranging from 3 to 4 (Table 13). Walsh et al. (2000) showed that Lorsban 15G controls cutworms in spearmint. Some other low EP alternative insecticides for control of cutworms include Asana XL, Avaunt 30WDG, Proclaim 5SG, tebufenozide (Confirm 2F), Lannate 90SP and cyfluthrin (Renounce 20 WP) (Kund et al. 2007, Kund et al. 2004, Lorenz et al. 2003). Diazinon is an alternative and is registered as Diazinon 14G, Diazinon 50W, and Diazinon AG600 WBC formulations, with EP values ranging from 1 to 4, that can be used for control of the cabbage maggot, seedcorn maggot, garden symphylans, wireworms and various worm pests pests. In addition to the low VOC insecticide products listed for cutworm control, these products can be used in broccoli for several other worm pests as well as Coragen 1.67SC, Synapse, Voliam Xpress, and Warior II Zeon Technology with an EP of 14.5. The formulated amount of the alternatives to be used was based on the 2006 PUR data, i.e., active ingredient per acre was modified to the amount of formulated product per acre (Table 11). The elimination of Lorsban 4E/Nufos 4E would increase costs to growers in the period of 2005 – 2007 by from $139,750 to $147,369 or about $12.98 per acre (Table 12).

Naled – Dibrom 8E, with an EP value of 39, is used on broccoli for control of aphids and lepidopterous larvae, e.g., green peach aphid, turnip aphid, cabbage aphid, cabbage looper (*Trichoplusia ni*), imported cabbage worm (*Pieris rapae*), diamondback moth (*Plutella zylostella*) and beet armyworm (*Spodoptera exigua*) (Chaney and Natwick 2007) (Table 13). Dibrom 8E was used on 15,723 acres in 2005 and 7,323 acres in 2007 and contributes approximately 4.1% and 2.2 % of the VOC emissions among all non-fumigant pesticides used on California broccoli for the 2005 to 2007 seasons, respectively (Tables 9 and 10). [I don't have the total emissions for just the insecticides – the percent of the total pesticides should be sufficient] Effective low EP alternatives for aphid control include: Durivo (a mixture of chloranthraniliprole and thiamethoxam with an EP of 12.3), thiamethoxam (Actara, Platinum 2SC and Platinum 75SG), Admire Pro, Alias 2F, Provado 1.6F, Assail 70WP, Assail 30 SG, Beleaf 50 SG and Fulfill 50WDG (Palumbo 2004 and Palumbo 2007a) (Table 13). Movento is another recently registered low VOC alternative for aphid control. The worm control alternatives listed for Lorsban 4E are also worm control alternatives for Dibrom 8E. Low EP alternative insecticides for control of lepidopteran larvae include: chlorpyrifos (Lorsban 50WP and Lorsban 75WG, with EP values of 3 and 3.7, respectively), methomyl (Lannate SP, with an EP value of 1), bifenthrin (Brigade 10WP, with an EP value of 1.9), esfenvalerate (Asana XL, with an EP value of 11.1), cyfluthrin (Renounce 20 WP, with an EP value of 1.9), zeta-cypermethrin (Mustang 1.5 EW, with an EP value of 6.8), indoxacarb (Avaunt 30WDG, with an EP value of 3.7), methoxyfenozide (Intrepid 2F, with an EP value of 4.8), emamectin benzoate (Proclaim 5SG, with an EP of 1), Entrust 80WP, Success 2SC, Radiant 1SC, and various *Bt* products (Hoy et al. 2006; Palumbo 2007b, Palumbo 2006, Palumbo 2003). A new low EP insecticide for control of lepidopteran larvae, rynaxypyr (chlorantraniliprole [Coragen 1.67SC]), has been very efficacious (Palumbo 2005). Other lepidopteracide alternatives include: Durivo, Synapse WG (flubendiamide), Voliam Xpress (lambda-cyhalothrin and chlorantraniliprole, with an EP of 17.6), and lambda-cyhalothrin (Warior II Zeon Technology, EP of 14.5). The formulated amount of the alternatives to be used was based on the 2006 PUR data, i.e., active ingredient per acre was modified to the amount of formulated product per acre would increase cost to growers in the period of 2005 – 2007 by $106,942 to $229,595 or about $14.60 per acre (Table 14).

Dimethoate – Dimethoate is marketed for use on broccoli in a number of EC formulations containing varying amounts (2.67 to 5.0 lbs) active ingredient per gal that all exceed the 20% EP level. Dimethoate is one of the most widely used insecticides on broccoli with 54,943 acres treated in 2005 and 45,605 acres treated in 2007 (Table 9). Dimethoate contributed 11.2% of the VOC emissions among non-fumigant pesticides used on California broccoli crops between 2005 and 2007 (Table 10). Dimethoate is widely used on broccoli for control of aphids such as green peach aphid (*Myzus persicae*), turnip aphid (*Lipaphis erysimi*) and cabbage aphid (*Brevicoryne brassicae*) and leafminers (*Liriomyza* spp.) (Chaney and Natwick 2007) (Table 15). Two low EP alternative insecticides for leafminer control are spinosad (Success 2SC and Entrust 80WP) with EP values of 2 and 6, respectively, and spinetoram (Radiant 1SC) with an EP value of 7.5 (Table 15). Success 2SC or Radiant 1SC would not increase the cost of leafminer control. Seal (2001) showed that spinosad is efficacious against the leafminer *Liriomyza trifolii* (Burgess) on bean and Schuster (2007) showed that spinetoram is efficacious against *L. trifolii* on tomato. Both spinetoram and spinosad are naturalyte insecticides that have low detrimental impact on most beneficial arthropods but can be toxic to predatory thrips, syrphid fly larva, and beetles 5 to 7 days after sprays; however, their use has not resulted in resurgence of insect pests or secondary outbreaks (Chaney and Natwick 2007). Cyromazine (Trigard 75WP), with an EP value of 1, is effective against *Liriomyza spp.* leafminer pests (Liu 2005) and would also be a cost effective replacement for dimethoate (Table 17). Trigard 75WP has a low potential for causing resurgence or secondary pest outbreaks. Actara (thiomethoxam) is a neonicotinoid that is an alternative to dimethoate for aphid control. Two neonicotinoid insecticides, imidacloprid (Admire Pro, Alias 2F and Provado 1.6F) and acetamiprid (Assail 70WP and Assail 30SG), with EP values from 1 to 5, provide excellent aphid control (Palumbo 2007a). Imidacloprid is most commonly used as an in-furrow application at planting, but can be used as a foliar spray. Imidacloprid used as a soil application is non-disruptive to most beneficial arthropods and provides excellent aphid control. Assail (70WP or 30 SG) or Provado 1.6F, used as foliar sprays, are efficacious against aphids and have low disruptive effects on beneficial arthropods; both would be cost effective alternatives (Table 15). Flonicamid (Beleaf 50SG), with an unknown EP value, and pymetrozine (Fulfill 50WDG, an azomethine aphicide), with an EP value of 1, are both alternatives to dimethoate that have low detrimental impact on beneficial arthropods and their use has not resulted in resurgence of insect pests or secondary outbreaks (Palumbo 2004 and Palumbo 2007a). Another insecticide alternative to dimethoate is spirotetramat (Movento). Movento is a fully systemic and ambimobile insecticide particularly effective against sucking pests, including aphids (Nauen et al. 2008 and Palumbo 2007a). None of the dimethoate alternatives listed provide both leafminer and aphid control simultaneously. Thus two insecticides might be needed to replace dimethoate. The formulated amount of the alternatives to be used was based on the 2006 PUR data, i.e. active ingredient per acre was modified to the amount of formulated product per acre (Table 15). The elimination of Dimethoate EC would increase cost to growers in the period of 2005 – 2007 by $1,360,850 to $1,639,508 or about $29.84 per acre (Table 16).

Diazinon – Diazinon 4E, Diazinon AG500 and others with EP values ranging from 39 to 44 are registered on broccoli for control of aphids, cabbage maggot, cutworms, flea beetles, garden symphylans, and wireworms (Chaney and Natwick 2007). Diazinon 4E and AG500 formulations were used on 14,024 acres in 2005 to 12,366 acres in 2007 and contributed 7.7% and 4.9% of the VOC emissions among the non-fumigant pesticides used in broccoli in California for 2005 and 2007, respectively (Tables 9 and 10). Diazinon 4E is no longer produced, but existing product that was purchased can still be used. Diazinon AG500 is also a 4 lb per gallon emulsifiable formulation, therefore the tables will only refer to Diazinon AG500 as the VOC producing formulation. Diazinon is also marketed for use on broccoli in a number of low EP formulations that include Diazinon 14G, Diazinon 50W, and Diazinon AG600 WBC, with EP values ranging from 2 to 5. These low EP formulations of diazinon and low EP formulations of chlorpyrifos (Lorsban 50W and Lorsban 75WG) could be used against the same pest spectrum as the high EP formulations of (Table 17). There are also a number of low EP alternative insecticides for control of aphids including neonicotinoid insecticides (Assail 30SG, Assail 70WP, Actara, Admire Pro, Alias 2F and Provado 1.6F), Beleaf 50SG and Fulfill 50WDG (Palumbo 2004 and Palumbo 2007). Low EP alternative insecticides for control of cutworms, aphids and flea beetles include Brigade 10WP, Asana XL, Renounce 20WP and Mustang 1.5EW (Chaney and Natwick 2007; Hoy and Dunlap 2007). Other low EP alternative insecticides for control of cutworms include Avaunt 30WDG, Proclaim 5SG, Confirm 2F, Lannate 90SP and Renounce 20WP (Kund et al. 2007, Kund et al. 2004, Lorenz et al. 2003) and other cutworm alternatives include: Durivo, Synapse WG (flubendiamide), Voliam Xpress (lambda-cyhalothrin and chlorantraniliprole, with an EP of 17.62), and lambda-cyhalothrin (Warior II Zeon Technology, EP of 14.5) (Table 17). The formulated amount of the alternatives to be used was based on 2006 PUR data, i.e., active ingredient per acre was converted to the amount of formulated product per acre (Table 17). The elimination of Diazinon 4E, Diazinon AG500 and others would increase cost to growers in the period of 2005 – 2007 by $179,196 to $203,222 about $14.49/acre (Table 18).

Oxydemeton – MSR Spray Concentrate with an EP value of 59 is the most widely used insecticide on broccoli for control of aphids (Chaney and Natwick 2007) and contributed 41.6% and 44.5 % of the VOC emissions among all non-fumigant pesticides used on California broccoli during the 2005 to 2007 seasons (Tables 9 and 10). In 2005, MSR Spray Concentrate was applied to 77,546 acres while in 2007 MSR Spray Concentrate was applied to 67,329 acres. Alternatives to MSR Spray Concentrate for aphid control include Movento, Beleaf 50SG, Fulfill 50WDG, Admire Pro, Alias 2F, Provado 1.6F, Assail 30SG and Assail 70WP and low EP formulations of Diazinon and Lorsban (Palumbo 2004 and Palumbo 2007a) as well as Actara and Platinum (Table 19). There would be a cost to growers of switching from MSR to alternative treatments. The elimination of MSR Spray Concentrate would increase cost to growers in the period of 2005 – 2007 by $169,965 to $195,758 or about $2.52 per acre (Table 20).

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Tables

Table 1. VOC producing herbicide application detail

Chemical Name	Trade Name	Pest(s) controlled	Number of Acres Treated [a]			Months of application	Rate Formulated Product/Acre/ Application [b]	% control
			2005	2006	2007			
bensulide	Prefar 4E	purslane burning nettle pigweed shepherd's purse barnyardgrass	10,092	9,967	8,424	Year-round	0.82 pt	80 50 80 10 90
oxyfluorfen	Goal 2XL	Little mallow burning nettle	12,141	11,030	8,660	Year round	1.5 pt	100 100
trifluralin	Treflan 4EC	purslane burning nettle pigweed shepherd's purse barnyardgrass	10,900	9,073	8,982	Year-round	1.28 pt	80 30 80 0 90

[a] Use rates from 2006 PUR data

[b] Formulated amount based on 2006 PUR data, i.e. active ingredient/ac modified to formulated amount/ac

Table 2. Amount (lbs) and percent of total VOC emission produced by herbicides active ingredients for 2005 through 2007 for broccoli

Chemical name	Trade name	2005		2006		2007	
		Amount[a]	Percent	Amount[a]	Percent	Amount[a]	Percent
bensulide	Prefar 4E	26.9	8.9	25.7	9.1	22.3	8.8
oxyfluorfen	Goal 2XL	12.0	4.0	12.6	4.5	10.6	4.2
trifluralin	Treflan 4EC	4.1	1.4	3.6	1.3	3.4	1.3

[a] Amount times 1000 pounds from 2005 to 2007 pesticide use report data and Dept of Pesticide Regulation.

Table 3. Alternatives to Prefar 4E application detail

Chemical/Generic Name	Trade Name	Pest(s) controlled	Number of Applications	Months of application(s)	Rate Formulated Product/Acre/ Application[a]	Application Method	% control
DCPA	Dacthal 75W	purslane burning nettle pigweed shepherd's purse barnyardgrass	1	Year-round	4.38 lb/ac	ground	80 40 80 10 90
napropamide	Devrinol 50DF	purslane burning nettle pigweed shepherd's purse barnyardgrass	1	Year-round	1.15 lb/ac	ground	80 40 80 50 90

[a]Formulated amount based on 2006 PUR data, i.e. active ingredient/ac modified to formulated amount/ac.

Table 4. Replacement cost of alternative scenarios for Prefar 4E

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Prefar 4E replacement acreage	Replacement cost[a] 2005	2006	2007
Purslane	Alternative 1	Dacthal 75W	100.24	25.0	252,896	249,764	211,107
		Devrinol 50DF	23.46	25.0	59,179	58,446	49,400
Burning Nettle	Alternative 2	Dacthal 75W	100.24	7.5	75,869	74,929	63,332
		Devrinol 50DF	23.46	7.5	17,754	17,534	14,820
Pigweed	Alternative 3	Dacthal 75W	100.24	10.0	101,159	99,906	84,443
		Devrinol 50DF	23.46	10.0	23,672	23,378	19,760
Barnyardgrass	Alternative 4	Dacthal 75W	100.24	7.5	75,869	74,534	63,332
		Devrinol 50DF	23.46	7.5	17,754	17,534	14,820
				100%	624,150	616,420	521,015
				Prefar 4E cost	650,335	642,280	542,872
				Difference in cost from change[b]	(26,184)	(25,860)	(21,858)

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 5. Alternatives to Goal 2XL application Detail

Chemical/Generic Name	Trade Name	Pest(s) controlled	Number of Applications	Months of application(s)	Rate per Treated Acre per Application	Application Method	% control
Oxyfluorfen	GoalTender	Little mallow burning nettle	1	Year round	.75 pt	ground	100 100

Table 6. Replacement cost of alternative scenarios for Goal 2XL

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Goal 2XL replacement acreage	Replacement cost[a] 2005	2006	2007
Broadleaf weeds	Alternative 4	GoalTender	35.23	100	427,709	388,558	305,054
				100%	427,709	388,558	305,054
				Goal 2XL cost	408,859	371,434	291,610
				Difference in cost from change[b]	18,850	17,124	13,444

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 7. Alternatives to Treflan application detail

Chemical/Generic Name	Trade Name	Pest(s) controlled	Number of Applications	Months of application(s)	Rate per Treated Acre per Application	Application Method	% control
DCPA	Dacthal 75W	purslane burning nettle pigweed shepherd's purse barnyardgrass	1	Year-round	4.38 lbs.	ground	80 40 80 10 90
napropamide	Devrinol 50DF	purslane burning nettle pigweed shepherd's purse barnyardgrass	1	Year-round	1.15 lbs.	ground	80 40 80 50 90

Table 8. Replacement cost of alternative scenarios for Treflan 4EC

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Treflan replacement acreage	Replacement cost[a] 2005	2006	2007
Purslane	Alternative 1	Dacthal 75W	100.24	20.00	218,509	181,877	180,058
		Devrinol 50DF	23.46	20.00	51,132	42,560	42,134
Burning Nettle	Alternative 2	Dacthal 75W	100.24	7.50	81,941	68,204	67,522
		Devrinol 50DF	23.46	7.50	19,175	15,960	15,800
Pigweed	Alternative 3	Dacthal 75W	100.24	11.25	122,911	102,306	101,283
		Devrinol 50DF	23.46	11.25	28,762	23,940	23,701
Barnyardgrass	Alternative 5	Dacthal 75W	100.24	11.25	122,911	102,306	101,283
		Devrinol 50DF	23.46	11.25	28,762	23,940	23,701
				100%	645,341	537,153	531,782
				Treflan 4EC cost	199,527	166,078	164,417
				Difference in cost from change[b]	445,813	371,076	367,365

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 9. VOC producing insecticide application detail

Chemical Name	Trade Name	Pest(s) controlled	Number Acres Treated[a] 2005	2006	2007	Months of application(s)	Rate Formulated Product/Acre/ Application[b]	% control
Chlorpyrifos	Lorsban 4E	cutworms, root maggots, symphylans, wireworms	11,353	10,725	10,766	Jan-Dec	2.5 pt	90
Naled	Dibrom 8E	lep. larvae, aphid	15,723	9,790	7,323	Jan-Dec	1.4 pt	85
Dimethoate	Dimethoate (267, 4EC, or 5EC)	aphids, leafminers	54,943	49,397	45,605	Jan-Dec	1 pt	90
Diazinon	Diazinon AG500	aphids, lep. larvae, flea beetle adults, root maggots, garden symphylans, wireworms	14,024	14,621	12,366	Jan-Dec	2.2 pt	90
Oxydemeton-methyl	MSR Spray Concentrate	aphids	77, 546	73,959	67,329	Jan-Dec	2.8 pt	90

[a] Use rates from 2006 PUR data.
[b] Formulated amount based on 2006 PUR data, i.e. active ingredient/ac modified to formulated amount/ac.

Table 10. Amount (lbs) and percent of total VOC emission produced by active ingredients for 2005 through 2007 in broccoli

		2005		2006		2007	
Chemical name	Trade name	Amount[a]	Percent	Amount[a]	Percent	Amount[a]	Percent
Chlorpyrifos	Lorsban 4E	20.9	6.9	18.6	6.6	17.3	6.8
Naled	Dibrom 8E	12.5	4.1	6.7	2.4	5.6	2.2
Dimethoate	Dimethoate (267, 4EC, or 5EC)	34.1	11.2	31.4	11.2	28.4	11.2
Diazinon	Diazinon AG500	23.2	7.7	18.8	6.7	12.5	4.9
Oxydemeton-methyl	MSR Spray Concentrate	126.2	41.6	121.5	43.2	112.9	44.5

[a] Amount times 1000 pounds from 2005 to 2007 pesticide use report data and Dept of Pesticide Regulation.

Table 11. Alternatives to Lorsban 4E application detail

Alternative	Chemical Name	Trade Name	Pest(s) controlled[a]	Number. Of Applications	Months of application	Rate Formulated Product/Acre/ Application [b]	Predominate Application Method	% control [c]
Alternative 1	chlorpyrifos	Lorsban Advanced	CRSW	1	Jan-Dec	4.5 pt	Ground	100
Alternative 2	chlorpyrifos	Lorsban 15G	CRSW	1	Jan-Dec	6.0 lb	Ground	100
Alternative 3	chlorpyrifos	Nufos 15G	CRSW	1	Jan-Dec	6.0 lb	Ground	100
Alternative 4	chlorpyrifos	Lorsban 50WP	CRSW	1	Jan-Dec	2.0 lb	Ground	100
Alternative 5	chlorpyrifos	Lorsban 75WG	CRSW	1	Jan-Dec	1.0 lb	Ground	100
Alternative 6	diazinon	Diazinon 50W	CRSW	1	Jan-Dec	6.0 lb	Ground	100
Alternative 7	diazinon	Diazinon 14G	CRSW	1	Jan-Dec	14.0 lb	Ground	100
Alternative 8	diazinon	Diazinon AG600	CRSW	1	Jan-Dec	4.75 pt	Ground	100
Alternative 9	esfenvalerate	Asana XL	cutworms	1	Jan-Dec	8.0 oz	Air	100
Alternative 10	cyfluthrin	Renounce 20WP	cutworms	1	Jan-Dec	2.0 oz	Air	100
Alternative 11	zeta-cypermethrin	Mustang 1.5EW	cutworms	1	Jan-Dec	3.4 oz	Air	100
Alternative 12	indoxacarb	Avaunt 30WDG	cutworms	1	Jan-Dec	3.0 oz	Air	100
Alternative 13	Methomyl	Lannate 90SP	cutworms	1	Jan-Dec	1.0 lb	Air	100
Alternative 14	emamectin benzoate	Proclaim 5SG	cutworms	1	Jan-Dec	4.0 oz	Air	100
Alternative 15	Chlorantraniliprole lambda-cyhalothrin	Voliam Xpress	cutworms	1	Jan-Dec	8.0	Air	100
Alternative 16	flubendiamide	Synapse WG	cutworms	1	Jan-Dec	2.0 oz	Air	100
Alternative 17	lambda-cyhalothrin	Warrior II ZT	cutworms	1	Jan-Dec	1.0 oz	Air	100

[a] CRSW: cutworms, root maggots, symphylans, wireworms
[b] Most use rates based on 2006 PUR data, i.e. active ingredient/ac modified to formulated amount/ac
[c] Compared to Lorsban 4E

Table 12. Replacement cost of alternative scenarios for Lorsban 4E

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Lorsban 4E replacement acreage	Replacement cost[a] 2005	2006	2007
	VOC	Lorsban 4E	25.00				
CRSW	Alternative 1	Lorsban Advanced	42.57	52	251,318	237,421	238,324
	Alternative 2	Lorsban 15G	23.58	5	13,385	12,645	12,693
	Alternative 3	Nufos 15G	20.82	5	11,819	11,165	11,208
	Alternative 4	Lorsban 50WP	33.58	5	19,062	18,008	18,076
	Alternative 5	Lorsban 75WG	29.10	5	16,519	15,605	15,665
	Alternative 6	Diazinon 50W	64.20	5	36,444	34,428	34,559
	Alternative 7	Diazinon AG600	39.64	5	22,501	21,256	21,337
Cutworms only	Alternative 8	Asana XL	19.14	2	4,346	4,106	4,121
	Alternative 9	Renounce 20WP	17.72	2	4,024	3,801	3,816
	Alternative 10	Mustang 1.5EW	17.88	2	4,059	3,835	3,850
	Alternative 11	Avaunt 30WDG	32.88	2	7,466	7,053	7,080
	Alternative 12	Lannate 90SP	43.12	2	9,791	9,250	9,285
	Alternative 13	Proclaim 5SG	54.62	2	12,402	11,716	11,761
	Alternative 14	Voliam Xpress	41.70	2	9,469	8,945	8,979
	Alternative 15	Synapse WG	22.10	2	5,018	4,741	4,759
	Alternative 16	Warrior II ZT	15.75	2	3,576	3,378	3,391
				100%	431,198	407,355	408,904
				Lorsban 4E cost	283,829	268,135	269,154
				Difference in cost from change[b]	147,369	139,220	139,750

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs.

Table 13. Alternatives to Dibrom 8EC application detail

Alternative	Chemical/Generic Name	Trade Name	Pest(s) controlled	Number of Applications	Months of application	Rate Formulated Product/Acre/ Application [a]	Predominate Application Method	% control [b]
Alternative 1	chlorpyrifos	Lorsban 50WP	lep. larvae, aphids	1	Jan-Dec	2.0 lb	Air	100
Alternative 2	chlorpyrifos	Lorsban 75WG	lep. larvae, aphids	1	Jan-Dec	1.0 lb	Air	100
Alternative 3	bifenthrin	Brigade 10WP	lep. larvae, aphids	1	Jan-Dec	8.0 oz	Air	100
Alternative 4	esfenvalerate	Asana XL	lep. larvae, aphids	1	Jan-Dec	8.0 oz	Air	100
Alternative 5	cyfluthrin	Renounce 20WP	lep. larvae, aphids	1	Jan-Dec	8.0 oz	Air	100
Alternative 6	zeta-cypermethrin	Mustang 1.5EW	lep. larvae, aphids	1	Jan-Dec	8.0 oz	Air	100
Alternative 7	thiamethoxam chlorantraniliprole	Durivo	lep. larvae, aphids	1	Jan-Dec	10.0 oz	Ground	100
Alternative 8	lambda-cyhalothrin chlorantraniliprole	Voliam Xpress	lep. larvae, aphids	1	Jan-Dec	8.0 oz	Air	100
Alternative 9	lambda-cyhalothrin	Warrior II ZT	lep. larvae, aphids	1	Jan-Dec	1.0 oz	Air	100
Alternative 10	flubendiamaid	Synapse WG	lep. larvae	1	Jan-Dec	2.0 oz	Air	100
Alternative 11	methomyl	Lannate SP	lep. larvae	1	Jan-Dec	1.0 lb	Air	100
Alternative 12	emamectin benzoate	Proclaim 5SG	lep. larvae	1	Jan-Dec	4.0 oz	Air	100
Alternative 13	indoxacarb	Avaunt 30WDG	lep. larvae	1	Jan-Dec	3.0 oz	Air	100
Alternative 14	rynaxypyr	Coragen 1.67SC	lep. larvae	1	Jan-Dec	5.0 oz	Air	100
Alternative 15	methoxyfenozide	Intrepid 2F	lep. larvae	1	Jan-Dec	8.0 oz	Air	100
Alternative 16	spinetoram	Radiant 1SC	lep. larvae	1	Jan-Dec	8.0 oz	Air	100
Alternative 17	spinosad	Success 2SC	lep. larvae	1	Jan-Dec	6.0 oz	Air	100
Alternative 18	spinosad	Entrust 80WP	lep. larvae	1	Jan-Dec	2.0 oz	Air	100
Alternative 19	imidacloprid	Admire Pro	aphids	1	Jan-Dec	7.0 oz	Ground	100
Alternative 20	imidacloprid	Provado 1.6F	aphids	1	Jan-Dec	3.8 oz	Air	100
Alternative 21	imidacloprid	Alias 2F	aphids	1	Jan-Dec	16.0 oz	Ground	100
Alternative 22	acetamiprid	Assail 70WP	aphids	1	Jan-Dec	1.0 oz	Air	100
Alternative 23	acetamiprid	Assail 30SG	aphids	1	Jan-Dec	2.5 oz	Air	100
Alternative 24	flonicamid	Beleaf 50SG	aphids	1	Jan-Dec	2.5 oz	Air	100
Alternative 25	pymetrozine	Fulfill 50WDG	aphids	1	Jan-Dec	2.75 oz	Air	100
Alternative 26	spirotetramat	Movento	aphids	1	Jan-Dec	5.0 oz	Air	100

[a] Most use rates based on 2006 PUR data, i.e. active ingredient/ac modified to formulated amount/ac.
[b] Compared to Dibrom 8EC.

Table 14. Replacement cost of alternative scenarios for Dibrom 8E

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Dibrom 8E replacement acreage	Replacement cost[a] 2005	2006	2007
	VOC	Dibrom 8E	23.88				
Lep. larvae except CL,	Alternative 1	Lorsban 50WP	35.08	4.0	22,062	13,738	10,276
Aphids except GPA	Alternative 2	Lorsban 75 WG	30.60	4.0	19,244	11,983	8,964
Lep. larvae & Aphids	Alternative 3	Brigade	34.02	6.0	32,093	19,984	14,948
	Alternative 4	Asana XL	19.14	6.0	18,056	11,243	8,410
	Alternative 5	Renounce 20WP	39.38	6.0	37,149	23,133	17,304
	Alternative 6	Mustang 1.5EW	27.86	6.0	26,282	16,366	12,242
	Alternative 7	Durivo	30.00	6.0	28,301	17,623	13,182
	Alternative 8	Voliam Xpress	41.70	6.0	39,338	24,496	18,323
	Alternative 9	Warrior II ZT	15.75	6.0	14,858	9,252	6,921
Lep. larvae only	Alternative 10	Synapse WG	22.10	2.0	6,949	4,327	3,237
	Alternative 11	Lannate 90SP	43.12	0.5	3,390	2,111	1,579
	Alternative12	Proclaim	54.62	0.5	4,294	2,674	2,000
	Alternative13	Avaunt 30WDG	32.88	0.5	2,585	1,610	1,204
	Alternative 14	Coragen SC	55.65	0.5	4,375	2,724	2,038
	Alternative 15	Intrepid 2F	34.18	0.5	2,687	1,673	1,252
	Alternative 16	Radiant 1SC	66.58	0.5	5,234	3,259	2,438
	Alternative 17	Success 2SC	52.50	0.5	4,127	2,570	1,922
	Alternative 18	Entrust 80WP	18.90	0.5	1,486	925	692
Aphids only	Alternative 19	Admire Pro	88.80	5.5	76,789	47,816	35,767
	Alternative 20	Provado 1.6F	31.29	5.5	27,054	16,847	12,601
	Alternative 21	Alias 2F	80.04	5.5	69,214	43,099	32,239
	Alternative 22	Assail 70WP	29.83	5.5	25,795	16,063	12,015
	Alternative 23	Assail 30SG	31.35	5.5	27,110	16,881	12,627
	Alternative 24	Beleaf 50SG	36.40	5.5	31,477	19,600	14,661
	Alternative 25	Fufill 50WDG	33.85	5.5	29,269	18,226	13,633
	Alternative 26	Movento	53.00	5.5	45,831	28,539	21,348
				100%	605,051	376,763	281,823
				Dibrom 8E cost	375,456	233,795	174,881
				Difference in cost from change[b]	229,595	142,968	106,942

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs.

Table 15. Alternatives to Dimethoate application detail

Alternative	Chemical/Generic Name	Trade Name	Pest(s) controlled	Number of Applications	Months of application(s)	Rate Formulated Product/Acre/ Application [a]	Predominate Application Method	% control [b]
Alternative 1	flonicamid	Beleaf 50SG	aphids	1	Jan-Dec	2.5 oz	Air	100
Alternative 2	pymetrozine	Fulfill 50WDG	aphids	1	Jan-Dec	2.75 oz	Air	100
Alternative 3	imidacloprid	Provado 1.6F	aphids	1	Jan-Dec	3.8 oz	Air	100
Alternative 4	acetamiprid	Assail 70WP	aphids	1	Jan-Dec	1.0 oz	Air	100
Alternative 5	acetamiprid	Assail 30SG	aphids	1	Jan-Dec	2.5 oz	Air	100
Alternative 6	imidacloprid	Admire Pro	aphids	1	Jan-Dec	7.0 oz	Ground	100
Alternative 7	imidacloprid	Alias 2F	aphids	1	Jan-Dec	16.0 oz	Ground	100
Alternative 8	spirotetramat	Movento	aphids	1	Jan-Dec	5.0 oz	Air	100
Alternative 9	thiamethoxam	Actara	aphids	1	Jan-Dec	3.0 oz	Air	100
Alternative 10	thiamethoxam	Platinum 2SC	aphids	1	Jan-Dec	10.0 oz	Ground	100
Alternative 11	thiamethoxam	Platinum 75SG	aphids	1	Jan-Dec	3.0 oz	Ground	100
Alternative 12	cyromazine	Trigard 75W	leafminers	1	Jan-Dec	2.66 oz	Air	100
Alternative 13	spinosad	Success 2SC	leafminers	1	Jan-Dec	6.0 oz	Air	100
Alternative 14	spinosad	Entrust 80WP	leafminers	1	Jan-Dec	2.0 oz	Air	100
Alternative 15	spinetoram	Radiant 1SC	leafminers	1	Jan-Dec	8.0 oz	Air	100

[a] Most use rates based on 2006 PUR data, i.e. active ingredient/ac modified to formulated amount/ac.

[b] Compared to Dimethoate.

Table 16. Replacement cost of alternative scenarios for Dimethoate

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Dimethoate replacement acreage	Replacement cost[a] 2005	2006	2007
	VOC	Dimethoate	15.86				
Aphids only	Alternative 1	Beleaf 50SG	36.40	8.0	159,994	143,843	132,801
	Alternative 2	Fufill 50WDG	33.85	8.0	148,775	133,756	123,488
	Alternative 3	Assail 70WP	29.83	8.0	131,116	117,880	108,831
	Alternative 4	Assail 30 SG	31.35	8.0	137,797	123,887	114,376
	Alternative 5	Provado 1.6F	31.29	8.0	137,516	123,634	114,143
	Alternative 6	Admire Pro	88.80	8.0	390,315	350,914	323,975
	Alternative 7	Alias 2F	80.04	8.0	351,811	316,297	292,016
	Alternative 8	Trigard 75W	27.52	10.0	151,225	135,959	125,522
	Alternative 9	Success 2 SC	52.50	8.0	230,760	207,466	191,539
	Alternative 10	Entrust 80WP	18.92	8.0	83,162	74,767	69,027
	Alternative 11	Radiant 1SC	66.58	2.0	73,162	65,777	60,727
Leafminers only	Alternative 12	Movento	53.00	12.0	349,437	314,163	290,045
	Alternative 13	Actara	34.80	1.50	28,680	25,785	23,806
	Alternative 14	Platinum	147.30	0.5	40,465	36,381	33,588
	Alternative 15	Platinum 75 SG	87.99	2.0	96,689	86,928	80,255
				100%	2,510,904	2,257,438	2,084,139
				Dimethoate cost	871,396	783,432	723,289
				Difference in cost from change[b]	1,639,508	1,474,006	1,360,850

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs.

Table 17. Alternatives to Diazinon AG500 application detail

Alternative	Chemical Name	Trade Name	Pest(s) controlled	Number of Applications	Months of application	Rate Formulated Product/Acre/ Application [a]	Predominate Application Method	% control [b]
Alternative 1	diazinon	Diazinon 50W	aphids, cutworms, root maggots, flea beetles, symphylans, wireworms	1	Jan-Dec	6.0 lb	ground	100
Alternative 2	diazinon	Diazinon AG600	aphids, cutworms, root maggots, flea beetles, symphylans, wireworms	1	Jan-Dec	4.75 pt	ground	100
Alternative 3	chlorpyrifos	Lorsban Advanced	cutworms, root maggots, symphylans, wireworms	1	Jan-Dec	4.5 pt	ground	100
Alternative 4	chlorpyrifos	Lorsban 15G	cutworms, root maggots, symphylans, wireworms	1	Jan-Dec	6.0 lb	ground	100
Alternative 5	chlorpyrifos	Lorsban 50WP	aphids, cutworms, root maggots, flea beetles, symphylans, wireworms	1	Jan-Dec	2.0 lb	ground	
Alternative 6	chlorpyrifos	Lorsban 75WG	aphids, cutworms, root maggots, flea beetles, symphylans, wireworms	1	Jan-Dec	1.0 lb	ground	100
Alternative 7	cyfluthrin	Renounce 20WP	cutworm, aphids, flea beetles	1	Jan-Dec	2.0 oz	air	100
Alternative 8	zeta-cypermethrin	Mustang 1.5EW	cutworm, aphids, flea beetles	1	Jan-Dec	3.4 oz	air	100
Alternative 9	bifenthrin	Brigade 10WP	cutworm, aphids, flea beetles	1	Jan-Dec	2.0 oz	air	100
Alternative 10	esfenvalerate	Asana XL	cutworm, aphids, flea beetles	1	Jan-Dec	3.4 oz	air	100
Alternative 11	lambda-cyhalothrin chlorantraniliprole	Voliam Xpress	cutworm, aphids, flea beetles	1	Jan-Dec	8.0 oz	air	100
Alternative 12	lambda-cyhalothrin	Warrior II ZT	cutworm, aphids, flea beetles	1	Jan-Dec	1.0 oz	Air	100
Alternative 13	emamectin benzoate	Proclaim 5SG	lep. larvae	1	Jan-Dec	4.0 oz	Air	100
Alternative 14	flubendiamaid	Synapse WG	lep. larvae	1	Jan-Dec	2.0 oz	Air	100
Alternative 15	flonicamid	Beleaf 50SG	aphids	1	Jan-Dec	2.5 oz	air	100
Alternative 16	pymetrozine	Fulfill 50WDG	aphids	1	Jan-Dec	2.75 oz	air	100
Alternative 17	imidacloprid	Provado 1.6F	aphids, flea beetles	1	Jan-Dec	3.8 oz	air	100
Alternative 18	acetamiprid	Assail 70WP	aphids, flea beetles	1	Jan-Dec	1.0 oz	air	100

Alternative 19	acetamiprid	Assail 30SG	aphids, flea beetles	1	Jan-Dec	2.5 oz	air	100
Alternative 20	thiamethoxam	Actara	aphids, flea beetles	1	Jan-Dec	3.0 oz	air	100
Alternative 21	Thiamethoxam	Platinum 2SC	aphids, flea beetles	1	Jan-Dec	10.0 oz	ground	100
Alternative 22	thiamethoxam	Platinum 75SG	aphids, flea beetles	1	Jan-Dec	3.0 oz	ground	100
Alternative 23	imidacloprid	Admire Pro	aphids, flea beetles	1	Jan-Dec	7.0 oz	ground	100
Alternative 24	imidacloprid	Alias 2F	aphids, flea beetles	1	Jan-Dec	16.0 oz	ground	100
Alternative 25	spirotetramat	Movento	aphids	1	Jan-Dec	5.0 oz	Air	100

[a] Most use rates based on 2006 PUR data, i.e. active ingredient/ac modified to formulated amount/ac.

[b] Compared to Diazinon 4E.

Table 18. Replacement cost of alternative scenarios for Diazinon AG500

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Dimethoate replacement acreage	Replacement cost[a] 2005	2006	2007
	VOC	Diazinon AG500	25.28				
Cutworms, root maggots, aphids, root maggots, flea beetles, symphylans, wireworms	Alternative 1	Diazinon 50W	64.20	13.00	117,040	122,023	103,203
	Alternative 2	Diazinon AG600	39.64	13.00	72,261	75,338	63,718
	Alternative 3	Lorsban 50WP	33.58	12.00	56,509	58,915	49,828
	Alternative 4	Lorsban 75 WG	29.10	5.00	20,404	21,273	17,992
	Alternative 5	Renounce 20 WP	17.72	2.00	4,970	5,182	4,382
	Alternative 6	Voliam Xpress	41.70	2.00	11,696	12,194	10,313
	Alternative 7	Warrior ll ZT	15.75	2.00	4,417	4,605	3,895
Cutworms, root maggots, symphylans, wireworms	Alternative 8	Lorsban Advanced	42.57	12.00	71,638	74,687	63,168
	Alternative 9	Lorsban 15G	23.58	5.00	16,534	17,238	14,579
Cutworms, Aphids, Flea beetles	Alternative 10	Proclaim	54.62	2.00	15,319	15,971	13,508
	Alternative 11	Synapse WG	22.10	4.00	12,397	12,925	10,931
	Alternative 12	Mustang 1.5 EW	17.88	2.00	5,014	5,228	4,421
	Alternative 13	Brigade	16.40	2.00	4,600	4,796	4,056
Cutworms and lep. larvae	Alternative 14	Asana XL	14.17	2.00	3,975	4,144	3,505
	Alternative 15	Beleaf 50SG	36.40	2.00	10,209	10,644	9,002
Aphids only	Alternative 16	Fufill 50WDG	33.85	2.00	9,493	9,897	8,371
	Alternative 17	Assail 70WP	29.83	3.00	12,550	13,084	11,066
	Alternative 18	Assail 30SG	31.35	2.00	8,793	9,167	7,753
Aphids & Fleas	Alternative 19	Actara	30.75	2.00	8,624	8,992	7,605
	Alternative 20	Platinum	43.20	2.00	12,116	12,632	10,684
	Alternative 21	Platinum 75 SG	73.58	2.00	20,636	21,514	18,196
	Alternative 22	Provado 1.6F	31.29	2.00	8,775	9,148	7,737
	Alternative 23	Admire Pro	88.80	1.00	12,453	12,983	10,981
	Alternative 24	Alias 2F	80.04	2.00	22,449	23,405	19,795
	Alternative 25	Movento	53.00	2.00	14,865	15,498	13,107
				100%	557,736	581,481	491,796
				Diazinon cost	354,514	369,607	312,601
				Difference in cost from change[b]	203,222	211,874	179,196

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs.

Table 19. Alternatives to MSR Spray Concentrate application detail

Alternative	Chemical/Generic Name	Trade Name	Pest(s) controlled	Number of Applications	Months of application(s)	Rate Formulated Product/Acre/ Application [a]	Predominate Application Method	% control [b]
Alternative 1	flonicamid	Beleaf 50WDG	aphids	1	Jan-Dec		Air	100
Alternative 2	pymetrozine	Fulfill 50WDG	aphids	1	Jan-Dec	2.75 oz	Air	100
Alternative 3	acetamiprid	Assail 70WP	aphids	1	Jan-Dec	1.0 oz	Air	100
Alternative 4	acetamiprid	Assail 30SG	aphids	1	Jan-Dec	2.5 oz	Air	100
Alternative 5	imidacloprid	Provado 1.6F	aphids	1	Jan-Dec	3.8 oz	Air	100
Alternative 6	thiamethoxam	Actara	aphids	1	Jan-Dec	3.0 oz	Air	100
Alternative 7	thiamethoxam	Platinum 2SC	aphids	1	Jan-Dec	10.0 oz	Ground	100
Alternative 8	thiamethoxam	Platinum 75SG	aphids	1	Jan-Dec	3.0 oz	Ground	100
Alternative 8	Imidacloprid	Admire Pro	aphids	1	Jan-Dec	7.0 oz	Ground	100
Alternative 10	imidacloprid	Alias 2F	aphids	1	Jan-Dec	16.0 oz	Ground	100
Alternative 11	spirotetramat	Movento	aphids	1	Jan-Dec	5.0 oz	Air	100

[a] Most use rates based on 2006 PUR data, i.e. active ingredient/ac modified to formulated amount/ac

[b] Compared to MSR Spray Concentrate

Table 20. Replacement cost of alternative scenarios for MSR Spray Concentrate

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of MSR Spray replacement acreage	Replacement cost[a] 2005	2006	2007
	VOC	MSR Spray	55.61				
Aphids	Alternative 1	Beleaf 50SG	36.40	11.0	310,495	296,131	269,584
	Alternative 2	Fufill 50WDG	33.85	10.0	262,475	250,332	227,891
	Alternative 3	Assail 70WP	29.83	8.50	196,622	187,526	170,715
	Alternative 4	Assail 30SG	31.35	8.50	206,641	197,082	179,414
	Alternative 5	Provado 1.6F	31.29	8.50	206,219	196,679	179,048
	Alternative 6	Actara	34.80	8.50	229,382	218,770	199,158
	Alternative 7	Platinum	145.80	8.50	961,030	916,571	834,405
	Alternative 8	Platinum 75 SG	86.49	8.50	570,093	543,719	494,977
	Alternative 9	Admire Pro	88.80	8.50	585,319	558,241	508,197
	Alternative 10	Alias 2F	80.04	8.50	527,578	503,171	458,064
	Alternative 11	Movento	53.00	11.0	452,094	431,180	392,526
				100%	4,507,948	4,299,403	3,913,981
				MSR cost	4,312,190	4,112,700	3,744,016
				Difference in cost from change[b]	195,758	186,702	169,965

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

[b] Positive number is savings, negative number is increase in costs.

Table 21. Use rate of alternative scenarios for Lorsban 4E

Target Pest(s)	Alternatives	Percent of Lorsban 4E replacement acreage
cutworms, root maggots, symphylans, wireworms	1, 2, 3, 4, 5, 6, 7 or 8	90%
cutworms only	9, 10, 11, 12, 13, 14, 15, 16 or 17	10%
		100%

Table 22. Use rate of alternative scenarios for Dibrom 8E

Target Pest(s)	Alternatives	Percent of Dibrom 8E replacement acreage
Lep. larvae except CL, aphids except GPA	1 or 2	15%
Lep. larvae & aphids	3, 4, 5, 6, 7, 8 or 9	30%
Worm pests only	10, 11, 12, 13, 14, 15, 16, 17 or 18	5%
Aphids only	19, 20, 21, 22, 23, 24, 25 or 26	50%
		100%

Table 23. Use rate of alternative scenarios for Dimethoate

Target Pest(s)	Alternatives	Percent of Dimethoate replacement acreage
Aphids only	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or 11	95%
Leafminers only	12, 13, 14, or 15	5%
		100%

Table 24. Use rate of alternative scenarios for Diazinon AG500

Target Pest(s)	Alternatives	Percent of Diazinon AG500 replacement acreage
cutworms, root maggots, symphylans, wireworms	3 or 4	35%
Aphids, cutworms, root maggots, flea beetles, symphylans, wireworms	1, 2, 5, or 6	43%
cutworms, aphids, flea beetles	7, 8, 9, 10, 11, or 12	5%
aphids only	15, 16 or 25	2%
aphids and flea beetles	17, 18, 19, 20, 21, 22, 23, or 24	3%
Cutworms and lep. larvae	13 or 14	2%
		100%

Table 25. Use rate of alternative scenarios for MSR Spray Concentrate

Target Pest(s)	Alternatives	Percent of MSR Spray Concentrate replacement acreage
aphids	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or 11	100%
		100%

Citrus

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California is the second leading state in citrus production in the United States. Only Florida produces more fruit than California. California citrus is produced for the fresh fruit market in contrast to Florida where much of the crop is grown for juice production. California citrus acreage totaled 271,730 acres in 2010 and it was comprised of 177,466 acres of navel and Valencia oranges, 44,477 acres of lemons, 38,826 acres of tangerines/tangelos and 10,500 acres of grapefruit/grapefruit hybrids. The California citrus crop was valued at $1.8 billion in 2010. About 75% of all citrus is grown in the San Joaquin Valley primarily along the foothills of Kern, Tulare, Fresno and Madera counties. For the economic aspects of this report, only oranges will be considered.

Citrus is a subtropical crop and is susceptible to low temperatures commonly experienced during the winter in California citrus production areas, particularly the inland valleys and desert. Historically, critical minimum temperatures are experienced from November to mid-February. During these episodes, fruit losses have been extensive, the most recent occurring in January of 2007. During cold episodes orchards with bare, weed-free soil conditions are warmer than orchards with significant growth on the orchard floor. Young trees commonly have tender immature foliage and are more susceptible to cold during these freeze events. Orchard floor management with pre-emergence and post-emergence herbicides is a passive strategy in a frost protection program. The San Joaquin Valley has the heaviest pesticide use due to extremes of temperatures that limit the efficacy of natural enemies. For example, 82% of chlorpyrifos use, 99% of dimethoate use, and 99% of fenpropathrin use occurred in the San Joaquin Valley in 2006.

Insecticides

Chlorpyrifos – Lorsban 4E/Nufos 4E with an EP value of 39.2 is widely used in citrus, primarily for control of citricola scale, katydids, citrus bud mite, ants and California red scale and to a lesser extent various secondary pests such as false chinch bug, Fuller rose beetle, rangeland grasshoppers, earwigs, glassy-winged sharpshooter, citrus rust mite, broad mite, woolly whitefly, whiteflies, purple scale, and various mealybugs. There are a number of alternative insecticides that can replace Lorsban 4E/Nufos 4E (Table 1). The 4E formulation of chlorpyrifos was applied to 98,371 acres 69,397 acres and 42,332 acres of oranges in 2005, 2006 and 2007, respectively at a use rate of approximately 6.5 pt/ac (Table 2). This use contributed 374,700, 240,600 and 143,500 lbs of VOC emissions into the atmosphere in 2005, 2006, and 2007, respectively (Table 3) and represents 42.3%, 32.1% and 22.7% of the VOC produced on oranges in 2005, 2006, and 2007, respectively.

Besides the emulsifiable concentration formulation, chlorpyrifos is also registered in a 3.76 EW (emulsion in water) formulation as Lorsban Advanced with an EP value of 18 (Table 4). Lorsban Advanced is a low odor and low VOC emitter and is a direct replacement for Lorsban 4E with equivalent efficacy against pests. Also, Lorsban Advanced is priced at the same level as Lorsban 4E. Lorsban 4E is especially critical for controlling citricola scale. Lorsban 4E is also especially important for controlling miscellaneous secondary pests and newly arrived exotic pests such as glassy-winged sharpshooter because Lorsban 4E is broad spectrum in activity. Years of use have selected for resistance in many natural enemies and so it is relatively IPM compatible.

The alternative low EP insecticides for citricola scale control include Admire 2F and Admire Pro (imidacloprid) with an EP of 1.2, Platinum and Platinum 75SG (thiamethoxam) with EP values of 0.4 and 2.04, Assail 70 WP (acetamiprid) with an EP of 1.9, Applaud 70 DF (buprofezin) with an EP 1.0, and petroleum oil with an EP < 2.0 (Table 4). These treatments are less effective in controlling citricola scale than a moderate to high rate (3-6lb/acre) of Lorsban 4E (Grafton-Cardwell and Reagan 2006, 2006c, Grafton-Cardwell and Scott 2007). Because citricola scale does not need males to reproduce and each female produces 1000 crawlers, incomplete control results in a rapid increase in the scale population. Chlorpyrifos, when applied carefully and at a moderate to high label rate (3-6 lb ai/acre), can suppress this pest for 2-3 years, reducing the number of treatments/year required. In contrast, treatments of Admire Pro, Assail 70WP or Applaud 70DF need to be applied nearly yearly. Oil treatments often require two applications per season. Because of poor efficacy and phytotoxic effects on the tree, oils are used primarily by organic growers who have no other control options. The results of lower efficacy of the alternatives to Lorsban 4E necessitates more frequent applications, which could potentially increase problems with air quality (equipment emissions), runoff into water, worker safety, and may compromise the citrus IPM system. Admire Pro, Platinum and Assail 70WP are broad spectrum insecticides that have been shown to cause secondary outbreaks of California red scale, especially after repeated use, and so use of these insecticides for citricola scale control needs to be minimized. The organophosphate Supracide 25 WP (methidathion) with an EP of 1.2, Lorsban Advanced with an EP of 18 and the carbamate, Sevin 80S (carbaryl) with an EP of 1.2 are also registered for citricola scale control, although they are disruptive of the citrus IPM program.

Because katydids are extremely sensitive to organophosphate and pyrethroid insecticides, the rate needed for their control is very low. San Joaquin Valley growers routinely mix Success (spinosad) with an EP of 4.8 for citrus thrips control with a low rate of either an organophosphate (0.6-.25 lb/acre Lorsban 4E or 0.13 to 0.5lb/acre Dimethoate 4E) or a pyrethroid (0.1 lb Baythroid or Renounce 20 WP or 0.3 lb Danitol 2.4 EC) to control katydids. Alternative low EP insecticides for katydid control include Renounce 20 WP (cyfluthrin) with an EP value of 1.9, Delegate WG (spinetoram) with an EP value of 3.7, Assail 70 WP with an EP value of 1.9, Altacor with an EP value of 3.7, Mustang with an EP value of 6.8, Lorsban Advanced, Micromite 80 WGS (diflubenzuron) with an EP value of 3.7, and Prokil Cryolite 96 (cryolite) with EP an value of 0.0 (Grafton-Cardwell and Reagan 2005, 2006d, 2007). Micromite is a slow acting insect growth regulator and cryolite is a slow acting stomach poison. Both of these insecticides are applied before petal fall when fruit is not present. The other three insecticides are faster acting and needed at petal fall to quickly prevent fruit damage. The newly registered insecticide Delegate is effective against citrus thrips and has a higher efficacy against katydids than Success because of greater persistence. Delegate treatments for citrus thrips may reduce or eliminate the need for tank mixes of Success with organophosphates and pyrethroids for katydid control and so greatly reduce chlorpyrifos use. However, research is needed to study the level of control that Delegate will exert.

Alternative low EP insecticides for California red scale include Lorsban Advanced with an EP of 18, Supracide 25W (methidathion) with an EP of 1.1, Sevin 80S/XLR Plus (carbaryl) with an EP of 1.2. However many populations of California red scale in the San Joaquin Valley have developed resistance to organophosphate and carbamate insecticides and so these treatments have declined since 1998 as other insecticides became available. Additional low EP insecticides for California red scale control include petroleum oils (EP < 2), Movento (spirotetramat) (EP = 10.6), and Applaud 70DF (EP = 1.0). Insectary-reared wasps (*Aphytis melinus*) can be released at a rate of 30,000 to 100,000 per acre for California red scale control.

Southern fire ants can feed on and damage the trunks of newly planted citrus trees. The solid baits (corn cob grits + soybean oil + toxicant) suitable for these red ants (Clinch ant bait (abamectin) and Esteem ant bait (pyriproxyfen)) are very slow acting and are designed for general population control, not protecting the trunks. Several newly registered liquid sugar baits (Vitis (imidacloprid), Gourmet ant bait (boric acid), Tango ant bait (methoprene)) only recently became available, but they are not effective on red ants. Growers use Lorsban 4E sprays on the trunks of young trees to attain quick control and stop trunk damage owing to red ants. There are no alternative trunk treatments. Lorsban 4E also is used for Argentine ant and native gray ant control. These ant species protect the honeydew producing citrus pests from their natural enemies. The soy + grit baits cannot be taken up by these ants and the liquid sugar baits will be more helpful in this situation. However, much research needs to be done to make liquid sugar + toxicant systems effective for ant control.

The cost of the low-VOC alternatives are variable, ranging from about $37.88/ac for Renounce 20WP to Admire Pro at $168.60 (Table 5). There are large numbers of available alternatives to Lorsban 4E for growers to select. However, based on the projected replacement of alternative insecticides, citrus growers will have increased insecticide costs (Table 6). We estimate that the cost of alternatives would have resulted in an increase of $1,564,294, $1,103,555 and $673,164 in 2005, 2006 and 2007, respectively, with an average increase per acre of $15.90.

Dimethoate – Cygon or Dimethoate 2.67/267/4EC/400 is used primarily for katydid and citrus thrips control and to a lesser extent citricola scale and sporadic secondary pests such as false chinch bug. Dimethoate was applied to 21,394, 25,189 and 34,727 acres of oranges in 2005, 2006 and 2007, respectively at an average use rate of 1.6 lbs active ingredient/acre (Table 2). This use contributed 45,200, 52,900 and 70,000 lbs of VOC emissions into the atmosphere in 2005, 2006, and 2007, respectively (Table 3) and represents 5.1%, 7.1% and 11.1% of the VOC produced on oranges in 2005, 2006, and 2007, respectively. There is no low EP formulation of dimethoate registered in California. However, there are several alternative low EP insecticides registered for control of these pests (Table 7). For katydid and citricola scale, see discussion for chlorpyrifos. For citrus thrips, Success or Entrust (spinosad) with an EP of 3.6 and 1.9, respectively, Renounce 20 WP (cyfluthrin) with an EP of 1.9, Mustang with an EP of 6.8, Veratran (sabadilla) with an EP of 1.9 and Delegate (spinetoram) with an EP value of 3.7, are registered insecticides. Some populations of citrus thrips have developed resistance to pyrethroids such as cyfluthrin and zeta-cypermethrin. Veratran is difficult for growers to obtain and less effective than the other insecticides, often requiring multiple treatments. Delegate and Success are similar chemistries and Delegate is likely to become the more commonly used product because of its greater persistence and efficacy against katydids.

The cost of the low-VOC alternatives are variable, ranging from about $37.88/ac for Renounce 20WP to $137.25 for Prokil Cryolite 96 (Table 8). Based on the projected replacement of alternative insecticides, citrus growers will have increased insecticide costs (Table 9). It is estimated that the cost of alternatives would have resulted in an increase of $813,651, $957,898 and $1,320,598 in 2005, 2006 and 2007, respectively with an average increase per acre of $38.00.

Fenpropathrin – Danitol 2.4EC is used primarily for katydid and citrus thrips control. Fenpropathrin was applied to 22,011 acres, 17,411 and 19,787 acres of oranges in 2005, 2006 and 2007, respectively at an average use rate of 19.7 oz formulated/acre (Table 2). This use contributed 16,500, 13,500 and 14,500 lbs of VOC emissions into the atmosphere in 2005, 2006, and 2007, respectively (Table 3) and represents 1.9%, 1.8% and 2.3% of the VOC produced on oranges in 2005, 2006, and 2007, respectively. There is no low EP formulation of fenpropathrin registered in California. However, there are several alternative low EP insecticides registered for control of these pests (Table 10). For katydid, see the discussion under chlorpyrifos. For citrus thrips, see the discussion under dimethoate.

The cost of the low-VOC alternatives are variable, ranging from about $37.88/ac for Renounce 20WP to $137.25 for Prokil Cryolite 96 (Table 11). Based on the projected replacement of alternative insecticides, citrus growers will have increased insecticide costs (Table 12). It is estimated that the cost of alternatives would have resulted in an increase of $569,564, $450,515 and $512,012 in 2005, 2006 and 2007, respectively with an average increase per acre of $25.88.

Herbicides

Oxyfluorfen – Goal 2XL is a commonly used herbicide in new plantings of oranges and was applied to 7,805, 8,326 and 6,426 acres in 2005, 2006 and 2007, respectively at an average use rate of 5 pt formulated/acre (Table 2). This use contributed 10,100, 10,800 and 8,300 lbs of VOC emissions into the atmosphere in 2005, 2006, and 2007, respectively (Table 3) and represents 1.1%, 1.4% and 1.3% of the VOC produced on oranges in 2005, 2006, and 2007, respectively. Oxyfluorfen is registered in citrus for non-bearing orchards only. It has a wide spectrum of activity on broadleaf weeds with pre-emergence and post-emergence activity (Table 13). It is commonly tank mixed with another preemergence herbicide such as oryzalin (Surflan A.S.) or pendimethalin (Prowl H20). Oxyfluorfen is formulated as an emulsifiable concentrate as Goal 2XL or as a flowable concentrate as GoalTender. The Goal 2XL has an EP of 39 while GoalTender has an EP of 5. GoalTender has equal pre-emergence activity to Goal 2XL, but only about one-half the post-emergence activity as Goal 2XL. Flumioxazin (Chateau SW and Chateau WDG) would be a good alternative and has a wide spectrum of activity.

Chateau SW has an EP value of 3.7. Chateau SW is registered for non-bearing citrus only. It has stronger pre-emergence activity than Goal 2XL but less post-emergence activity.

The cost of GoalTender is $62.17 per treated acre, which is more costly than Goal 2XL at $54.00 per treated acre (Table 14). The cost of Chateau SW is $32.77 per acre, which is less costly than Goal 2XL. Based on the projected replacement of Goal 2XL with GoalTender and Chateau SW, citrus growers will have increased herbicide costs (Table 15). It is estimated that the cost of the low VOC alternative would have resulted in an slight increase of $40,850, $43,557 and $33,632 in 2005, 2006 and 2007, respectively with an average increase per acre of $5.20.

Plant Growth Regulators

Gibberellic Acid – Gibgro 4LS or ProGibb 4% are predominantly used as plant growth regulators (PGR) in navel oranges to delay rind aging and were applied to 42,621 48,464 and 51,669 acres in 2005, 2006 and 2007, respectively, at an average use rate of 30 oz formulated/acre (Table 2). This use contributed 86,600, 101,400 and 108,900 lbs of VOC emissions into the atmosphere in 2005, 2006, and 2007, respectively (Table 3) and represents 9.8%, 13.5% and 17.2% of the VOC produced on oranges in 2005, 2006, and 2007, respectively. Applications of Gibgro 4LS or ProGibb 4% are typically made to navel oranges in foliar sprays to the tree canopy in the fall to early winter. Maximum response to Gibgro 4LS or ProGibb 4% applications occurs shortly before rind color break in September or early October in the San Joaquin Valley. The EP value for Gibgro 4LS or ProGibb 4% is 95 and Gibgro 4LS or ProGibb 4% is used on 90% to 100% of the crop. The high usage of this liquid formulation of gibberellic acid is related to familiarity with the product and perceived ease of use. The liquid formulations allow growers to easily adjust the amount of product per acre. The prepackaged dry product is much more difficult to adjust. However the cost per gram of active ingredient between dry and liquid formulations is comparable and the efficacy between the dry and liquid products is similar. Transition to dry formulation would significantly reduce the potential for volatile emissions. Use of non-liquid formulations carries significantly greater risk in dosage errors, owing to the large variation in active ingredient among formulations and the difficulty in measurement of non-liquid formulations in the field. Additional prepackaging of non-liquid formulations with containers holding the same quantity of active ingredient as currently being used in applications with liquid formulations might increase use of low EP products. Research needs to be conducted to identify what incentives would be effective in encouraging transition to non-liquid formulations by users. There are a number of low-VOC emitting formulations of gibberellic acid (Gibgro 20% Powder, ProGibb Plus 2x 20%, GA3 4% and N-Large Premier. All the low-VOC formulations have EP values of less than 6.

The cost of the low-VOC alternatives ranges from about $25.90/ac for N-Large Premier to $67.00 for ProGibb Plus 2x 20% (Table 17). However, based on the projected replacement of alternative PGR, citrus growers will see little economic impact (Table 18). It is estimated that the cost of alternatives would have resulted in a decrease of $59,456; $67,607 and $72,078 in 2005, 2006 and 2007, respectively, with an average decrease per acre of $1.40.

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Tables

Table 1. VOC Producing Pesticides and Alternatives

	Materials	Yield loss (%)	Quality change
VOC Producing Pesticide	**Lorsban 4E**		
Alternative 1	Lorsban Advanced	0%	None
Alternative 2	Platinum 75SG	0%	None
Alternative 3	Platinum	0%	None
Alternative 4	Admire 2F	0%	None
Alternative 5	Admire Pro	0%	None
Alternative 6	Assail 70WP	0%	None
Alternative 7	Applaud 70DF	0%	None
Alternative 8	Supracide 25WP	0%	None
Alternative 8	Sevin 80S	0%	None
Alternative 10	Sevin XLR Plus	0%	None
Alternative 11	Petroleum Oil	0%	None
Alternative 12	Delegate WG	0%	None
Alternative 13	Renounce 20WP	0%	None
Alternative 14	Micromite 80WGS	0%	None
Alternative 15	Prokil 96	0%	None
Alternative 16	Vendex 50WP	0%	None
Alternative 17	Movento	0%	None
Alternative 18	Altacor	0%	None
Alternative 19	Mustang	0%	None
VOC Producing Pesticide	**Dimethoate 4E**		
Alternative 1	Delegate WG	0%	None
Alternative 2	Renounce 20WP	0%	None
Alternative 3	Micromite 80WGS	0%	None
Alternative 4	Prokil Cryolite 96	0%	None
Alternative 5	Success	0%	None
Alternative 6	Entrust	0%	None
Alternative 7	Veratran D	0%	None

Alternative 9	Altacor	0%	None
Alternative 10	Mustang	0%	None
			None
VOC Producing Pesticide	**Danitol 2.4EC**		
Alternative 1	Delegate WG	0%	None
Alternative 2	Renounce 20WP	0%	None
Alternative 3	Micromite 80WGS	0%	None
Alternative 4	Prokil Cryolite 96	0%	None
Alternative 5	Success	0%	None
Alternative 6	Entrust	0%	None
Alternative 7	Veratran D	0%	None
Alternative 8	Altacor	0%	None
Alternative 9	Mustang	0%	None
VOC Producing Pesticide	**Goal 2XL**		
Alternative 1	Goal Tender	0%	None
Alternative 2	Chateau SW	0%	None
VOC Producing Pesticide	**Gibgro 4LS or ProGibb 4%**		
Alternative 1	Gibgro 20% Powder	0%	None
Alternative 2	ProGibb Plus 2X (20%)	0%	None
Alternative 3	GA3 4%	0%	None
Alternative 4	N-Large Premier	0%	None

Table 2. VOC Producing Pesticides - Application Details

Chemical name	Trade name	Pest(s) controlled	No. acres treated[a] 2005	2006	2007	Months of appls.	Rate form ac/ appl[b]	% control
Chlorpyrifos	Lorsban 4E	Citricola scale, California red scale, katydids, citrus bud mite, ants, secondary pests	98,371	69,397	42,332	Apr-Oct	6.50 pt	100
Dimethoate	Dimethoate 4E	Citrus thrips, katydids, secondary pests	21,394	25,189	34,727	Apr-Sep	3.00 pt	100
Fenpropathrin	Danitol 2.4EC	Citrus thrips, katydids, secondary pests	22,011	17,411	19,787	Apr-Jun	19.70 fl.oz	100
Oxyfluorfen	Goal 2XL	Broadleaf weeds	7,805	8,326	6,426	Mar-Jun	18.00 fl.oz	100
Gibberellic Acid	Gibgro 4LS and ProGibb 4%	Delayed rind aging	42,621	48,464	51,669	Sep-Dec	30.00 fl. oz	100

[a] Use rates from 2005 to 2007 pesticide use report data.

[b] Formulated amount based on 2005 pesticide use report data i.e. active ingredient/ac modified to formulated amount/ac.

Table 3. Amount (lbs) and percent of total VOC emission produced by active ingredients for 2005 through 2007 in oranges

		2005		2006		2007	
Chemical name	Trade name	Amount[a]	Percent	Amount[a]	Percent	Amount[a]	Percent
Chlorpyrifos	Lorsban 4E	374.7	42.3	240.6	32.1	143.5	22.7
Dimethoate	Dimethoate 4E	45.2	5.1	52.9	7.1	70.0	11.1
Fenpropathrin	Danitol 2.4EC	16.5	1.9	13.5	1.8	14.5	2.3
Oxyfluorfen	Goal 2XL	10.1	1.1	10.8	1.4	8.3	1.3
Gibberellic Acid	Gibgro 4LS/ ProGibb 4%	86.6	9.8	101.4	13.5	108.9	17.2

[a] Amount times 1000 pounds from 2005 to 2007 pesticide use report data and Dept. of Pesticide Regulation.

Table 4. Alternative insecticides to Lorsban 4E - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl.[a]	Appl. method	Percent control[b]
Chlorpyrifos	Lorsban Advanced	Citricola scale and	1	May-Oct	12 pt	Ground	100[c]
Spirotetramat	Movento	California	1	May-Oct	10 fl oz	Ground	100
Buprofezin	Applaud 70DF	red scale	1	May-Sep	46.00 oz	Ground	80
Methidathion	Supracide 25W		1	May-Oct	12.00 lb	Ground	100[c]
Carbaryl	Sevin 80S		1	May-Oct	13.25 lb	Ground	80[c]
Carbaryl	Sevin XLR Plus		1	May-Oct	10.50 qt	Ground	80[c]
Petroleum Oil	Petroleum Oil		2	May-Sep	10.00 gal	Ground	70
Chlorpyrifos	Lorsban Advanced	Citricola scale only	1	Aug-Oct	12 pt	Ground	100[c]
Thiamethoxam	Platinum		1	Aug-Oct	11 fl oz	Ground	70
Thiamethoxam	Platinum 75SG		1	May-Sep	3.67 oz	Ground	70
Imidacloprid	Admire 2F		1	May-Sep	32.00 fl.oz	Ground	70
Imidacloprid	Admire Pro		1	May-Sep	14.00 fl.oz	Ground	70
Acetamiprid	Assail 70WP		1	Mar-Oct	5.7 oz	Ground	100
Buprofezin	Applaud 70DF		1	Aug-Sep	46.00 oz	Ground	80
Methidathion	Supracide 25WP		1	Aug-Oct	12.00 lb	Ground	100[c]
Carbaryl	Sevin 80S		1	Aug-Sep	13.25 lb	Ground	80[c]
Carbaryl	Sevin XLR Plus		1	Aug-Sep	10.50 qt	Ground	80[c]
Petroleum Oil	Petroleum Oil		2	Mar-Sep	10.00 gal	Ground	50
Chlorpyrifos	Lorsban Advanced	Citrus bud mite only	1	Apr-Jun	1.00 lb	Ground	100
Fenbutatin-oxide	Vendex 50WP		1	Apr-Jun	2 lb	Ground	70
Chlorpyrifos	Lorsban Advanced	Katydid only	1	May-Jun	1 pt	Ground	100
Acetamiprid	Assail 70WP		1	May-Jun	2.5 oz	Ground	100
Spinetoram	Delegate WG		1	May-Jun	6.40 oz	Ground	100
Cyfluthrin	Renounce 20WP		1	May-Jun	8.00 oz	Ground	100
Diflubenzuron	Micromite 80WGS		1	Apr-Jun	6.25 oz	Ground	80
Cryolite	Prokil Cryolite 96		1	Apr-Jun	20 lb	Ground	80
Zeta-cypermethrin	Mustang		1	Apr-Jun	4.3 oz	Ground	100
Rynaxypyr	Altacor		1	Apr-Jun	3 oz	Ground	100

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Lorsban 4E.
[c] Unless the population has resistance, in which case percent control drops to 70%.

Table 5. Cost of Lorsban 4E and replacement cost of alternative insecticides for Lorsban 4E

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac [a]
Chlorpyrifos	**Lorsban 4E**	**8.64**	**pt**	**6.5**	**Ground**	**41.60**	**57.60**
			Citricola and Calif. red scale				
Chlorpyrifos	Lorsban Advanced	8.64	pt	6.0	Ground	51.84	67.84
Spirotetramat	Movento	9.22	fl. oz	10.0	Ground	92.20	108.20
Buprofezin	Applaud 70DF	2.65	oz	46.00	Ground	121.90	137.90
Methidathion	Supracide 25WP	9.75	lb	12.00	Ground	117.00	133.00
Carbaryl	Sevin 80S	8.72	lb	13.25	Ground	115.54	131.54
Carbaryl	Sevin XLR Plus	13.63	qt	10.50	Ground	143.12	159.12
Petroleum Oil	Petroleum Oil	5.25	gal	10.00	Ground	105.00	137.00
			Citricola scale only				
Chlorpyrifos	Lorsban Advanced	8.64	pt	6.0	Ground	51.84	67.84
Thiamethoxam	Platinum	13.68	fl. Oz	11.0	Ground	92.20	108.20
Thiamethoxam	Platinum 75SC	25.83	fl. Oz	3.67	Ground	94.80	110.80
Imidacloprid	Admire 2F	6.77	fl.oz	32.00	Ground	216.64	232.64
Imidacloprid	Admire Pro	11.40	fl.oz	14.00	Ground	159.60	175.60
Acetamiprid	Assail 70WP	19.33	oz	5.7	Ground	110.18	126.18
Buprofezin	Applaud 70DF	2.65	oz	46.00	Ground	121.90	137.90
Methidathion	Supracide 25WP	9.75	lb	12.00	Ground	117.00	133.00
Carbaryl	Sevin 80S	8.72	lb	13.25	Ground	115.54	131.54
Carbaryl	Sevin XLR Plus	13.63	qt	10.50	Ground	143.12	159.12
Petroleum Oil	Petroleum Oil	5.25	gal	10.00	Ground	105.00	137.00
			Citrus bud mite only				
Chlorpyrifos	Lorsban Advanced	8.64	pt	1.0	Ground	8.65	24.65
Fenbutatin-oxide	Vendex 50WP	34.59	lb	2.0	Ground	69.18	85.18
			Katydid only				
Chlorpyrifos	Lorsban Advanced	8.64	pt	1.0	Ground	8.65	24.65
Acetamiprid	Assail 70WP	19.33	oz	2.5	Ground	48.33	64.33
Spinetoram	Delegate WG	9.34	oz	6.40	Ground	59.78	75.78
Cyfluthrin	Renounce 20WP	3.61	oz	8.00	Ground	28.88	44.88
Diflubenzuron	Micromite 80WGS	7.40	oz	6.25	Ground	46.25	62.25
Cryolite	Prokil Cryolite 96	3.00	lb	20.00	Ground	60.00	76.00
Rynaxypyr	Altacor	15.72	oz	3.0	Ground	47.16	63.16
Zeta-cypermethrin	Mustang	2.41	fl. oz	4.3	Ground	10.36	26.36

[a] Application cost of ground speed sprayer is $16.00/ac.

Table 6. Replacement cost of alternative scenarios for Lorsban 4E

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Lorsban 4E replacement acreage	Replacement cost[a]		
					2005	2006	2007
Citricola scale and California red scale	Alternative 1	Lorsban Advanced	67.84	2	133,469	94,158	57,436
	Alternative 12	Movento	108.20	10	1,064,371	750,877	458,032
	Alternative 7	Applaud 70DF	137.90	2	271,306	191,397	116,752
	Alternative 8	Supracide 25WP	133.00	2	261,666	184,596	112,603
	Alternative 9	Sevin 80S	131.54	1	129,397	91,285	55,683
	Alternative 10	Sevin XLF Plus	159.12	1	156,523	110,421	67,356
	Alternative 11	Petroleum Oil	137.00	4	539,072	380,296	231,979
Citricola scale only	Alternative 1	Lorsban Advanced	67.84	35.00	2,335,714	1,647,765	1,005,130
	Alternative 3	Platinum	108.20	2.00	212,874	150,175	91,606
	Alternative 2	Platinum 75SG	110.80	2.00	217,982	153,779	93,804
	Alternative 4	Admire 2F	232.64	2.00	457,699	322,891	196,962
	Alternative 5	Admire Pro	175.60	2.00	345,478	243,723	148,670
	Alternative 6	Assail 70WP	126.18	5.00	620,626	437,830	267,074
	Alternative 7	Applaud 70DF	137.90	1.00	135,653	95,699	58,376
	Alternative 8	Supracide 25WP	133.00	1.00	130,833	92,298	56,301
	Alternative 9	Sevin 80S	131.54	1.00	129,397	91,285	55,683
	Alternative 10	Sevin XLR Plus	159.12	1.00	156,523	110,421	67,356
	Alternative 11	Petroleum Oil	137.00	1.00	134,768	95,074	57,995
Citrus bud mite only	Alternative 1	Lorsban Advanced	24.65	4.00	96,994	68,426	41,739
	Alternative 17	Vendex 50WP	85.18	3.00	251,377	177,337	108,175
Katydid only	Alternative 1	Lorsban Advanced	17.00	4.00	66,892	47,190	28,786
	Alternative 6	Assail 70WP	64.33	3.00	189,831	133,919	81,690
	Alternative 13	Delegate WG	75.78	3.00	223,624	157,759	96,232
	Alternative 14	Renounce 20WP	44.88	4.00	176,595	124,582	75,994
	Alternative 15	Micromite 80WGS	62.25	1.00	61,236	43,200	26,352
	Alternative 16	Prokil cryolite 96	76.00	1.00	74,762	52,742	32,172
	Alternative 18	Altacor	63.16	1.00	62,131	43,831	26,737

Alternative 19	Mustang	26.36	1.00	25,933	18,295	11,160
		88.06	100%	8,662,725	6,111,250	3,727,838
		Cost of Lorsban 4E		7,098,431	5,007,695	3,054,674
		Difference in cost[b]		(1,564,294)	(1,103,555)	(673,164)

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs.

Table 7. Alternative insecticides to Dimethoate 4E - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl[a]	Appl method	% control[b]
Spinetoram	Delegate WG	Katydid and	1	May-Jun	6.4 oz	Ground	100
Cyfluthrin	Renounce 20WP	Citrus thrips	1	May-Jun	8.0 oz	Ground	100
Spinosad	Success		1	May-Jun	6.0 fl.oz	Ground	100
Spinosad	Entrust		1	May-Jun	3.0 oz	Ground	100
Zeta-cypermethrin	Mustang		1	May-Jun	4.0 oz	Ground	100
Diflubenzuron	Micromite 80WGS	Katydid only	1	Apr-Jun	6.25 oz	Ground	80
Cryolite	Prokil cyrolite 96		1.5	Apr-Jun	20.0 lb	Ground	80
Rynaxypr	Altacor		1	Apr-Jun	3.0 oz	Ground	100
Spinetoram	Delegate WG	Citrus Thrip	1	May-Jun	6.4 oz	Ground	100
Spinosad	Success	only	1	May-Jun	6.0 fl.oz	Ground	100
Spinosad	Entrust		1	May-Jun	3.0 oz	Ground	100
Sabadilla	Veratran D		1	May-Jun	15.0 lb	Ground	80

[a] Most use rates based on 2005 pesticide use report data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Dimethoate 4E
[c] Restrictions in water protection areas.

Table 8. Replacement cost of alternative insecticides to Dimethoate 4E

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl method	Total material cost/ac	Total material & appl. cost/ac [a]
Dimethoate	**Dimethoate 4E**	**6.85**	**pt**	**3.00**	**Ground**	**20.55**	**36.55**
			Katydid and citrus thrips				
Spinetoram	Delegate WG	9.34	oz	6.40	Ground	59.78	75.78
Cyfluthrin	Renounce 20WP	3.61	oz	8.00	Ground	28.88	44.88
Spinosad	Success	7.00	fl.oz	6.00	Ground	42.00	58.00
Spinosad	Entrust	33.68	oz	3.00	Ground	101.04	117.04
Zeta-cypermethrin	Mustang	2.41	fl. oz	4.2	ground	10.36	26.36
			Katydid only				
Diflubenzuron	Micromite 80WGS	7.40	oz	6.25	Ground	46.25	62.25
Rynaxpyr	Altacor	15.72	oz	3.0	Ground	47.16	63.16
Cryolite	Prokil Cryolite 96	3.00	lb	20.00	Ground	90.00	114.00
			Citrus Thrips only				
Spinetoram	Delegate WG	9.34	oz	6.4	Ground	59.78	75.78
Spinosad	Success	7.00	fl.oz	6.00	Ground	42.00	58.00
Spinosad	Entrust	33.68	oz	3.00	Ground	101.04	117.04
Sabadilla	Veratran D	3.98	lb	15.00	Ground	59.70	75.70

[a] Total material cost per treated acre plus application cost of $16.00 per acre times number of applications.

Table 9. Replacement cost of alternative scenarios for Dimethoate 4E

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Dimethoate 4E replacement acreage	Replacement cost[a] 2005	2006	2007
Katydid and Citrus thrips	Alternative 1	Delegate WG	75.78	25	405,285	477,189	657,872
	Alternative 2	Renounce 20WP	44.88	20	192,031	226,100	311,711
	Alternative 5	Success	58.00	10	124,084	146,099	201,418
	Alternative 6	Entrust	117.04	15	375,591	442,226	609,671
	Alternative 9	Mustang	26.36	2	11,280	13,281	18,310
Katydid only	Alternative 3	Micromite 80 WGS	62.25	3	39,953	47,041	64,853
	Alternative 4	Prokil Cryolite 96	63.16	1	13,512	15,910	21,934
	Alternative 8	Altacor	114.00	1	24,389	28,716	39,589
Citrus Thrips only	Alternative 1	Delegate WG	75.78	15	243,171	286,313	394,723
	Alternative 5	Success	58.00	2	24,817	29,220	40,284
	Alternative 6	Entrust	117.04	5	125,197	147,409	203,224
	Alternative 7	Veratran D	75.70	1	16,195	19,068	26,288
			74.58	100%	1,595,506	1,878,571	2,589,878
			Cost of Dimethoate 4E		781,946	920,674	1,269,280
			Difference in cost[b]		(813,561)	(957,898)	(1,320,598)

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs.

Table 10. Alternative insecticides to Danitol 2.4EC - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl [a]	Appl method	% control [b]
Spinetoram	Delegate WG	Katydid and	1	May-Jun	6.40 oz	Ground	100
Cyfluthrin	Renounce 20WP	Citrus thrips	1	May-Jun	8.00 oz	Ground	100
Spinosad	Success		1	May-Jun	6.00 fl.oz	Ground	100
Spinosad	Entrust		1	May-Jun	3.00 oz	Ground	100
Zeta-cypermethrin	Mustang Max EC		1	May-Jun	4.3 oz	Ground	100
Diflubenzuron	Micromite 80WGS	Katydid only	1	Apr-Jun	6.25 oz	Ground	80
Cryolite	Prokil Cyrolite 96		1.5	Apr-Jun	20 lb	Ground	80
Cyazypyr	Altacor		1	Apr-Jun	3 oz	Ground	100
Spinetoram	Delegate WG	Citrus thrips	1	May-Jun	6.40 oz	Ground	100
Spinosad	Success	only	1	May-Jun	6.00 fl.oz	Ground	100
Spinosad	Entrust		1	May-Jun	3.00 oz	Ground	100
Sabadilla	Veratran D		1	May-Jun	15.00 lb	Ground	80

[a] Most use rates based on 2005 pesticide use report data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Dimethoate 4E
[c] Restrictions in water protection areas.

Table 11. Replacement cost of alternative insecticides to Danitol 2.4EC

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl method	Total material cost/ac	Total material & appl. cost/ac [a]
Fenpropathrin	**Danitol 2.4EC**	**1.66**	**oz**	**19.70**	**Ground**	**32.70**	**48.70**
			Katydid and citrus thrips				
Spinetoram	Delegate WG	9.34	oz	6.40	Ground	59.78	75.78
Cyfluthrin	Renounce 20WP	3.61	oz	8.00	Ground	28.88	44.88
Spinosad	Success	7.00	fl.oz	6.00	Ground	42.00	58.00
Spinosad	Entrust	33.68	oz	3.00	Ground	101.04	117.04
Zeta-cypermethrin	Mustang	2.41	fl.oz	4.30	Ground	10.36	26.36
			Katydid only				
Diflubenzuron	Micromite 80WGS	7.40	oz	6.25	Ground	46.25	62.25
Cryolite	Prokil Cryolite 96	3.00	lb	20.0	Ground	60	114.00
Rynaxypyr	Altacor	15.72	oz	3	Ground	47.16	63.16
			Citrus Thrips only				
Spinetoram	Delegate WG	9.34	oz	6.40	Ground	59.78	75.78
Spinosad	Success	7.00	fl.oz	6.00	Ground	42.00	58.00
Spinosad	Entrust	33.68	oz	3.00	Ground	101.04	117.04
Sabadilla	Veratran D	3.98	lb	15.00	Ground	59.70	75.70

[a] Total material cost per treated acre plus application cost of $9.00 per acre times number of applications.

Table 12. Replacement cost of alternative scenarios for Danitol 2.4EC

Target pest(s)	Alternatives	Trade name	Cost per Acre	Percent of Danitol 2.4EC replacement acreage	Replacement cost[a] 2005	2006	2007
Katydid and Citrus thrips	Alternative 1	Delegate WG	75.78	25	416,986	329,828	374,851
	Alternative 2	Renounce 20WP	44.88	20	197,575	156,279	177,611
	Alternative 5	Success	58.00	10	127,667	100,982	114,767
	Alternative 6	Entrust	117.04	15	386,434	305,662	347,387
	Alternative 9	Mustang	26.36	2	11,606	9,180	10,433
Katydid only	Alternative 3	Micromite 80WGS	62.25	3	41,106	32,515	36,953
	Alternative 4	Prokil Cryolite 96	114.00	1	25,093	19,848	22,558
	Alternative 8	Altacor	63.16	1	13,902	10,997	12,498
Citrus thrips only	Alternative 1	Delegate WG	75.78	15	250,191	197,897	224,911
	Alternative 5	Success	58.00	2	25,533	20,196	22,953
	Alternative 6	Entrust	117.04	5	128,811	101,887	115,796
	Alternative 7	Veratran D	75.70	1	16,663	13,180	14,979
			74.58	100%	1,641,568	1,298,452	1,475,695
			Cost of Danitol 2.4EC		1,072,004	847,936	963,683
			Difference in cost[b]		(569,564)	(450,515)	(512,012)

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs.

Table 13. Alternative insecticides to Goal 2XL - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl. [a]	Appl. method	Percent control [b]
Oxyfluorfen	GoalTender	Broadleaf weeds	1	Mar-Jun	4 pt	Ground	80
Flumioxazin	Chateau SW	Broadleaf weeds	1	Mar-Jun	6 oz	Ground	85

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Goal 2XL.

Table 14. Cost of Goal 2XL and replacement cost of alternative insecticides for Goal 2XL

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac [a]
Oxyfluorfen	**Goal 2XL**	**16.48**	**pt**	**7**	**Ground**	**38.00**	**54.00**
Oxyfluorfen	GoalTender	35.04	pt	4	Ground	46.17	62.17
Flumioxazin	Chateau SW	8.47	oz	6	Ground	16.77	32.77

[a] Application cost of ground speed sprayer is $16.00/ac.

Table 15. Replacement cost of alternative scenarios for Goal 2XL

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Goal 2XL replacement acreage	Replacement cost[a] 2005	2006	2007
Broadleaf weeds	Alternative 1	GoalTender	62.17	90	436,738	465,892	359,575
Broadleaf weeds	Alternative 2	Chateau SW	32.77	10	25,577	27,285	21,058
			94.94	100%	462,316	493,176	380,633
			Cost of Goal 2XL		421,466	449,600	347,001
			Difference in cost[b]		(40,850)	(43,577)	(33,632)

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs.

Table 16. Alternative insecticides to Gibgro 4LS and ProGibb 4% - Application Details

		No.	Months appls.	appl.[a]	Appl.	Percent
Gibberellic Acid	Gibgro 20% Powder	1	Sept. - Dec.	150.00 g	Ground	100
Gibberellic Acid	ProGibb Plus 2x 20%	1	Sept. - Dec.	150.00 g	Ground	100
Gibberellic Acid	GA3 4%	1	Sept. - Dec.	30.00 oz	Ground	100
Gibberellic Acid	N-Large Premier	1	Sept. - Dec.	15.00 oz	Ground	100

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.

[b] Compared to Gibgro 4LS and ProGibb 4%.

Table 17. Cost of Gibgro 4LS and ProGibb 4% and replacement cost of alternative insecticides for Gibgro 4LS and ProGibb 4%

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac[a]
Gibberellic Acid	**Gibgro 4LS/ProGibb 4%**	**1.67**	**oz**	**30.00**	**Ground**	**50.40**	**66.10**
Gibberellic Acid	Gibgro 20% Powder	0.34	g	150.00	Ground	51.00	67.00
Gibberellic Acid	ProGibb Plus 2x 20%	0.34	g	150.00	Ground	51.00	67.00
Gibberellic Acid	GA3 4%	1.68	oz	30.00	Ground	50.40	66.40
Gibberellic Acid	N-Large Premier	0.66	oz	15.00	Ground	9.90	25.90

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 18. Replacement cost of alternative scenarios for Gibgro 4LS/ProGibb 4%

Alternatives	Trade name	Cost per acre	Percent of Gibgro 4LS replacement acreage	Replacement cost[a] 2005	2006	2007
Alternative 1	Gibgro 20% Powder	67.00	40	1,142,243	1,298,835	1,384,729
Alternative 2	ProGibb Plus 2x (20%)	67.00	40	1,142,243	1,298,835	1,384,729
Alternative 3	GA3 4%	66.40	15	424,505	482,701	514,623
Alternative 4	N-Large Premier	25.90	5	55,194	62,761	66,911
			100%	2,764,185	3,143,133	3,350,993
			Cost of Gibgro 4LS	2,823,641	3,210,740	3,423,071
			Difference in cost[b]	59,456	67,607	72,078

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

[b] Positive number is savings, negative number is increase in costs.

Cotton

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Cotton is produced on about 300,000 acres in California. The majority of the production is concentrated in the southern San Joaquin Valley with minor production occurring in the lower deserts and Sacramento Valley. California Department of Pesticide Regulation (DPR) has identified a number of pesticides used on cotton as contributing volatile organic compounds (VOC) to air quality problems in California. DPR is proposing to regulate pesticides with evaporate potentials (EP) of greater than 20 percent. Cotton is the largest VOC contributor of all agricultural commodities in California. Cotton contributed over 500,000 lbs of VOC producing materials from emulsifiable concentration formulations in 2005. The top six VOC producing pesticides and non-VOC producing alternative pesticides or formulations are discussed with regard to pest control activity and IPM potential.

Insecticides & Miticides

Chlorpyrifos – Lorsban 4E, with an EP value of 51, along with naled (Dibrom 8E), with an EP value of 39, and dimethoate (Dimethoate E267 and other EC formulations), with EP values of 39 to 63, are used to manage cotton aphids and silverleaf whiteflies. Cotton aphids and silverleaf whiteflies can be major pests of cotton during several points in the growing season. Early-season populations (pre-squaring) have been uncommon in recent years and under present conditions are frequently controlled by beneficial arthropods when they do occur. During the mid-season period (squaring to initial boll opening), aphids and whiteflies can build-up to levels that can negatively impact cotton yields. This frequently occurred (especially with cotton aphids) in the mid to late 1990s and the damage potential and management costs arising from this situation were evident. During the last 5+ years, mid-season infestations of aphids and whiteflies have been limited but the concern is still present. Infestations of these insect pests during the late-season period (after initial boll opening until harvest) has been the greatest concern during the 2000s. Aphids and whiteflies excrete honeydew during feeding and the deposition of this sticky substance on exposed cotton lint can greatly reduce the quality of the commodity. Sticky cotton lint compromises the ginning and yarn spinning processes and reduces the suitability of the lint. This, at the very least, creates a negative impression of the lint from a given production region and reduces the demand for that lint and ultimately the price paid. The high reproductive potential of aphids and whiteflies, extreme mobility of these insects (especially whitefly adults), low threshold number of aphids and whiteflies that can result in sticky cotton, high level of scrutiny of cotton lint quality, and large cotton canopy which protects the insects from insecticide applications (coupled with them feeding on the leaf undersides) contribute to this difficult situation. Also in recent years, San Joaquin Valley cotton acreage has transitioned to Pima cotton from Acala cotton with approximately 66% of the cotton planted being Pima cotton. Pima cotton requires a longer growing season than Acala cotton and the lint is used for finer, higher value fabrics, which places even greater importance on lint quality.

Lorsban 4E is one of the most effective products for the late-season infestations of cotton aphids (Table 1). Lorbsan 4E was widely used on cotton and was applied to 390,194, 256,692 and 46,862 acres in 2005, 2006 and 2007, respectively (Table 2). The amount of VOC produced by Lorsban 4EC varied from 406,473 lbs in 2005 to 47,201 lb in 2007 and accounted for 24% to 7.5% of the total VOC produced on cotton (Table 3). The fuming activity of Lorsban 4E, which contributes to the VOC concerns, is instrumental for allowing the toxicant to reach the aphids on the leaf undersides within the large canopy. This is particularly important with an aerial application, which is the common (and perhaps only viable) application method on late-season cotton. Emulsifiable concentrate formulations of naled and dimethoate also can be applied to late-season infestations of cotton but are not as efficacious as Lorsban 4E. Lorsban Advanced (3.76 EW), which is a new water-based formulation of chlorpyrifos with very low VOC emissions (EP of 18), has been evaluated with Lorsban 4E in small plot tests with ground application (Table 4). Lorsban Advanced consistently provided 60-80% of the control that was seen with Lorsban 4E and thus two applications of Lorsban Advanced will be required to provide equivalent control as Lorsban 4E (Godfrey, unpublished data?). Other alternatives for aphid management include imidacloprid (Provado 1.6F), acetamiprid (Assail 70WP), and thiamethoxam (Centric 30WG), with EP values of 5, 2 and 4, respectively. These products are all in the neonicotinoid insecticide class and overuse of these materials creates the potential for the development of resistance. This class of chemistry is already commonly used on San Joaquin Valley cotton for thrips (seed treatments), lygus bug, and whitefly management. Preliminary data from cotton in the southern United States show that resistance has developed in cotton aphids to Centric 30WG in 2006. This is the first confirmed report of neonicotinoid resistance by cotton aphid in the field. Additional alternatives for cotton aphid control include carbofuran (Furadan 4F), with an EP value of 7. Furadan 4F was registered under a Section 18 for several years in the 1990s and was extremely effective against late-season aphids. However, recent federal regulatory actions against this active ingredient make it unlikely as a viable alternative. Flonicamid (Carbine), with an EP value of 3.7, has recently been registered and is effective against cotton aphids. It is in a different class of chemistry than the neonicotinoids and in small plot testing has provided comparable aphid control to Lorsban 4E and Assail 70WP. Also, pymetrozine (Fulfill 50WG), with an EP value of 1, is registered on cotton and represents a different class of chemistry and mode of action but is not marketed on cotton.

An alternative control for whitefly management is the insect growth regulator buprofezin (Courier 40SC), with an EP value of 1 (Table 4). Courier 40SC is an effective product when applied during the mid-season. It is slow to act but provides long residual control and is best used to mitigate a developing infestation. Spiromesifin (Oberon 2SC), with an EP value of 5.7, and Dinotefuran (Venom 20SG), with an EP value of 3.7, are newly registered materials that provide good whitefly control primarily with mid-season applications but also have some utility during the late-season period. Venom 20SG is a neonicotinoid insecticide so the application of Venom 20SG along with Assail 70WP and Provado 1.6F would increase the selection pressure and possibilities for resistance in aphids and whiteflies to this class of chemistry. The other neonicotinoid products, especially Assail 70WP, but also Provado 1.6 F and Centric 30WG to a limited degree, are suitable for late-season control of whiteflies. For late-season, quickly developing whitefly infestations, a pyrethroid insecticide synergized with an organophosphate (OP) insecticide is the most effective treatment. These infestations develop when other neighboring crops senesce and cotton is the last green field in the area and thus invaded by "waves" of whitefly adults. As with aphid management, this is a critical time for protecting lint quality. Several pyrethroid-OP combinations are available for use and are similarly effective but Lorsban 4E, Dibrom 8E and Dimethoate 267 are common OPs used for this treatment. Pyrethroid insecticides are notorious for flaring cotton aphid populations in cotton and using one of the OP partners helps to keep the aphids in check along with providing whitefly control. Aldicarb (Temik 15G), with an EP value of 1, is also an alternative product to aid in mid-season arthropod pest control. This systemic product is applied in the soil at layby, "activated" into the plant with irrigation, and has residual systemic activity within the plant for up to four weeks. Populations of lygus bugs, cotton aphids, spider mites, and whiteflies are controlled/suppressed by this insecticide. This carbamate product broadens the range of chemical classes used in cotton but has drawbacks of expense, toxicity and restricted application timing, i.e., must be applied before layby when soil is dry and well before bloom. This product is scheduled to be withdrawn from use in 2014.

In terms of non-chemical management of aphids and whiteflies, several cultural practices are important contributors. Optimal irrigation termination, nitrogen fertilization, and defoliation timing in conjunction with practical yield targets are important factors. Minimizing the use of broad-spectrum insecticides help to preserve the population of generalist predators that feed on these pests. Vigorous cotton varieties and use of proper IPM sampling and management strategies help overall with cotton production.

For aphid control, all alternatives except Assail 70WP and Lorsban Advanced were estimated to require one application to provide similar control to Lorsban 4E (Table 4). Assail 70WP would require two applications at the low rate for aphids and two applications at the high rate of sliverleaf whitefly. The cost of material and application of the alternatives for cotton aphid control was estimated to range from approximately $16.84 to $88.80 per acre (Table 5). The cost of material and application of the alternatives for silverleaf whitefly control was estimated to range from approximately $41.88 to $106.92 per acre (Table 5). The elimination of Lorsban 4E would have cost cotton growers a projected $10,985,362, $7,226,801 and $1,319,334 for 2005, 2006 and 2007, respectively, with an average increase in cost of less than $28.20 per acre (Table 6). Thus, the elimination of Lorsban 4E would have a major economic impact in cotton.

Oxamyl – This active ingredient is used primarily for lygus bug management. Although cotton aphid can also be a target and as such is listed in Table 7, oxamyl is not really a stand-alone product for cotton aphids. Vydate C-LV was used on cotton and was applied to 138,340, 92,916 and 17,903 acres in 2005, 2006 and 2007, respectively (Table 2). The amount of VOC produced by Vydate C-LV varied from 74,345 lbs in 2005 to 9,599 lbs in 2007 and accounted for 4.5% to 1.5% of the total VOC produced on cotton (Table 3). Lygus bugs can be a yield-limiting pest in some years in some fields. Population severity is closely linked to winter/early spring rainfall patterns and to surrounding crops that can act as source of lygus bugs moving into cotton. Lygus bugs damage cotton by removing fruiting structures and therefore limiting boll production. There are some options for cultural control measures aiding in lygus bug management such as border harvesting of alfalfa and management of weed hosts in the vicinity of cotton fields. Manipulative biological control does not play an important role. Field location and the environmental conditions are the principal factors influencing lygus bug numbers.

Organophosphate insecticides used to be the standard for lygus bug control but they have mostly either 1) been removed from the market due to numerous regulatory concerns or 2) lost activity on lygus bugs due to resistance build-up. Acephate is the one exception but the use of this active ingredient in San Joaquin Valley cotton is limited due to documented flaring of spider mite populations following acephate application. There are no other foliar carbamate products available for lygus bug management in cotton besides oxamyl. Aldicarb is used as a side-dress application but the recent announcement of the imminent loss of this registration will remove this product. Pyrethroid insecticides, including cyfluthrin, lambda-cyhalothrin, and zeta-cypermethrin, have been the "standard" for lygus bug management from the early 1990s to ~2005. This class of chemistry is still used but insecticide resistance has and is continuing to severely limit the utility of these materials. In addition, pyrethroid insecticides have the added drawback of flaring populations of spider mites and cotton aphids in cotton. Flonicamid is currently the "product of choice" for managing lygus bugs in cotton. This active ingredient is fairly new (~4 to 5 years), has no documented negative impacts on beneficial insects in cotton, and has a unique mode of action. It has a weak direct toxicity effects on lygus bug adults but stops their feeding, leading to eventual death. The effects on lygus bug nymphs are quicker and more direct. Since this active ingredient is also one of the mainstays for cotton aphids, there is concern over repeated exposure of lygus bugs and the possibility of developing resistance, i.e., lack of rotation of active ingredients/modes of action. During recent years, growers facing heavy lygus bug pressure in cotton have not been able to adequately manage this pest given all insecticidal options currently available.

The cost of material and application of the alternatives for cotton aphid and lygus bug control was estimated to range from approximately $17.64 to $88.80 per acre (Table 8). The elimination of Vydate C-LV would increase the cost to cotton growers a projected $405,921, $272,637 and $52,534 for 2005, 2006 and 2007, respectively, with an average increase in cost of about $2.00 per acre (Table 9). Thus, the elimination of Vydate C-LV would have minor adverse economic impact in cotton.

Abamectin – Zephyr 0.15EC (several generic brand names also exist all of the 0.15EC formulation), with an EP value of 55, is highly effective and widely used for control of spider mites in cotton. Zephyr 0.15EC was applied to 320,683, 250,327, and 211,551 acres of cotton in 2005, 2006, and 2007, respectively (Table 2). Pounds of VOC emissions produced by applications of Zephyr 0.15EC equaled 64,730, 47,273 and 37,572 lbs in 2005, 2006, and 2007, respectively and accounted for 3.5% to 6.0% of the total VOC produced on cotton (Table 3). Zephyr 0.15EC has been the most used material for spider mite control in cotton for the last 15 years. Dicofol (Kelthane MF) and propargite (Comite) are the other two long-standing options for spider mite control in San Joaquin Valley cotton. However, regulatory concerns and increased levels of resistance have greatly hindered the applicability of these two products. During the last 5+ years, four new miticides have been registered for spider mite control and three of these new materials are viable alternatives to Zephyr 0.15EC. Spiromesifen (Oberon 2SC, EP value of 5.7), etoxazole (Zeal, EP value of 4), and bifenazate (Acramite 4SC, EP value of 6), are all useful alternatives that provide similar control to Zephyr 0.15EC (Tables 1 and 10). These products all have some drawbacks such as inconsistent performance (Acramite 4SC) and slow performance (Zeal) but as more is learned about how to best use these products, they will be the mainstays of spider mite management in San Joaquin Valley cotton.

The cost of material and application of the alternatives for spider mite control was estimated to range from approximately $20.40 to $85.16 per acre (Table 11). The elimination of Zephyr 0.15EC would decrease the cost to cotton growers a projected $19,555,634, $15,265,241 and $12,900,634 for 2005, 2006 and 2007, respectively, with an average decrease in cost of less that $61.00 per acre (Table 12). Thus, the elimination of Zephyr 0.15EC would have no adverse economic impact in cotton. The decrease in cost is the result of the reduced cost of the new miticide particularly Zeal. Thus it is expected that both Zeal and Oberon will largely replace Zephyr 0.15 EC with/without governmental regulation over concerns for the VOC issue with Zephyr 0.15 EC.

Herbicides

Trifluralin – Treflan HFP, Treflan 4D and others, with EP values ranging from 39 to 53, are applied as a preplant incorporated herbicide for control of grasses and several broadleaf weeds. Treflan can also be applied as a layby treatment before irrigation ditches are formed. Pendimethalin (Prowl H_2O), with an EP value of 3, is a low VOC alternative to Treflan that provides comparable weed control. The use of Treflan or Prowl is the foundation for weed management programs in cotton because of cost and ability to control many weed species (Table 13). The number of acres treated with Treflan was 197,185 and 96,308 for 2005 and 2007, respectively, and contributed 170,481 and 94,043 lbs of VOC or about 10 to 15% of the non-fumigant VOC produced on cotton (Tables 14 and 15). Cotton growers who relied solely on glyphosate on Roundup Ready varieties and did not apply Treflan or Prowl later suffered when weed populations shifted. Throughout the United States, weed specialists recommend using a dinitroaniline herbicide (Treflan or Prowl) for pre-emergence control along with any herbicide tolerant cotton program. Prowl H_20 is now registered for late season applications that are applied in the irrigation water or as a spray before irrigation. There is often a need for this application due to late season grasses emerging even after 2 to 3 glyphosate applications. Cultivation both prior to planting and during the season is still being used in most of the cotton production systems in California. The cost of fuel, dust, and labor makes this more expensive and produces less desirable air quality. The total cost (product + application costs) of Treflan HFP is $16.28 per acre, while the cost of Prowl H_2O was $30.03 (Table 17). If the acreage receiving Treflan was entirely replaced with Prowl H_2O, it estimated that the low VOC products would have increased grower costs by $12,134,372, to $10,620,607 in 2005, to 2007, respectively or about $13.75 per acre (Table 18).

Oxyfluorfen – Goal 2XL, with an EP value of 62, provides control of several broadleaf weeds and partial control of some grasses. This herbicide is used for winter weed control as a “fallow bed” treatment. Goal 2XL is applied 1 to 3 months before planting to maintain prepared beds free of weeds. There are a number of low VOC alternatives available that provide equivalent control (Table 19). Goal 2XL was used to treat 196,140 and 64,823 acres for 2005 and 2007, respectively, and contributed 136,060 and 69,525 lbs of VOC or about 8.2 to 11.1% of the non-fumigant VOC produced on cotton (Tables 14 and 15). A new formulation of oxyfluorfen, (GoalTender) with an EP value of 5, was registered in California in 2005 for use in cotton. This herbicide has provided successful control of weeds in experiments in the San Joaquin Valley. Therefore, it may be possible to replace Goal 2XL with GoalTender, a product with a higher percent active ingredient, lower volatility, lower ‘lift-off’ potential, and similar price as Goal 2XL (Table 20). Other options include carfentrazone (Shark), with an EP value of 1.0, and flumioxazin (Chateau), with an EP value of 3.7. Both herbicides provide excellent control of broadleaf weeds. Paraquat is another option. Glyphosate (Roundup), with an EP value of 4.8, is usually included with the broadleaf herbicides to control both broadleaves and grasses (Table 19). Tillage can also be used to remove weeds ahead of cotton planting, but this can only be done when the weather is favorable and soil conditions are somewhat dry.

During the cotton season, Goal 2XL is sometimes used for control of annual morning glory and other broadleaves as a directed spray. Goal 2XL is now being replaced by more effective herbicides like carfentrazone (Shark), pyraflufen (ET), flumioxazin (Chateau), glufosinate (Rely 280), diuron (Layby Pro), prometryn (Caparol), and glyphosate (Roundup, Touchdown etc). However, Roundup can only be applied to Roundup Ready cotton varieties. Glufosinate can be applied at layby once the plants are tall but earlier on “Liberty Link” varieties. Currently there are no “Liberty Link” Acala or Pima varieties available. Some growers are using glufosinate while growing Liberty Link non-Acala upland varieties for seed. A disadvantage of diuron and prometryn is that their plant-back restrictions. All low VOC alternatives have a similar or lower cost per acre than Goal 2XL (Table 20). The total cost (product + application costs) of Goal 2XL is $65.55 per acre, while alternatives range from $57.17 for GoalTender to $17.12 for ET herbicide (Table 20). It is estimated that a complete substitution for Goal 2XL with low VOC products would have saved growers $30,605,113, $32,550,809, and $27,709,504 based on treated acreages in 2005, 2006, and 2007, respectively, or a reduction in herbicide costs of about $17.00 per acre or 30% (Table 21).

Pendimethalin – Pendimethalin, formulated as Prowl 3.3EC, has an EP of 42. Pendimethalin is a pre-emergent herbicide, i.e. applied prior to cotton planting. Prowl 3.3EC is effective on annual grasses and some broadleaf weeds (Table 22). Prowl 3.3EC was used to treat 103,479 and 26,205 acres for 2005 and 2007, respectively, and contributed 126,570 and 33,397 lbs of VOC or about 7.6 to 4.8% of the non-fumigant VOC produced on cotton (Tables 13 and 14). An alternative to Prowl 3.3 EC is Prowl H_2O. Prowl H_2O is a water-based formulation, and thus has a lower EP than Prowl 3.3 EC, which is a petroleum solvent-based formulation. Prowl H_20 is also registered for late season applications that are applied in irrigation water or as a spray before irrigation. Under a Roundup Ready system, it is sometimes necessary for this application because of late season grasses, even after 2 to 3 glyphosate applications. The total cost (product + application costs) of Prowl 3.3 EC is $24.38 per acre, while the cost of Prowl H_2O is $30.03 (Table 23). If the acreage receiving Prowl 3.3 EC was completely replaced with Prowl H2O, it estimated that the lower VOC product would have increase grower costs by $1,840,596 to $3,241,645 in 2005 to 2007, respectively (Table 24). This represents an increase in herbicide cost of about $5.65 per acre or about 23%.

Tables

Table 1. VOC producing insecticides and alternatives

	Materials	Yield loss (%)	Quality change (%)
VOC Producing Pesticide	**Lorsban 4E**	5-10	5
Alternative 1 – cotton aphids	Carbine 50WG	0	0
Alternative 2 – cotton aphids	Assail 70WP	0	0
Alternative 3 – cotton aphids	Provado 1.6F	10-20	10
Alternative 4 – cotton aphids	Centric WG	10-20	10
Alternative 5 – cotton aphids	Lorsban Advanced	10-15	10
Alternative 6 – cotton aphids	Temik 15G[A]	30	30
VOC Producing Pesticide	**Lorsban 4E**	5-10[B]	5%
Alternative 7 – silverleaf whitefly	Courier 40SC	0	5
Alternative 8 – silverleaf whitefly	Oberon 2SC	5	5
Alternative 9 – silverleaf whitefly	Assail 70WP	5	5
Alternative 10 – silverleaf whitefly	Venom 20 SG, Venom 70WG	5	5
VOC Producing Pesticide	**Vydate C-LV**	25	15
Alternative 1 – cotton aphids	Carbine 50WG	0	0
Alternative 2 – cotton aphids	Assail 70WP	0	0
Alternative 3 – cotton aphids	Provado 1.6F	10-20	10
Alternative 4 – cotton aphids	Centric WG	10-20	10
Alternative 5 – cotton aphids	Lorsban Advanced	10-15	10
Alternative 6 – cotton aphids	Temik 15G[A]	30	30

[A] only useful and applicable during the early portion of the season (not the most critical period).
[B] must be tank-mixed with an OP or carbamate to achieve this level of control, applied alone the control would be 30%.
[C] must be applied preventatively so not a remedial product; would not maintain control until the late-season period where quality is compromised.

Table 1. Continued

	Materials	Yield loss (%)	Quality change (%)
VOC Producing Pesticide	**Vydate C-LV**	10	0
Alternative 7 – Lygus bugs	Carbine 50WG	5	0
Alternative 8 – Lygus bugs	Warrior with Zeon, Warrior II	10-20	0
Alternative 9 – Lygus bugs	Leverage 2.7	10-20	0
Alternative 10 – Lygus bugs	Mustang Max	10-20	0
Alternative 11 – Lygus bugs	Temik 15G[C]	25	0
Alternative 12 – Lygus bugs	Orthene 75S	15-20	0
VOC Producing Pesticide	**Zephyr 0.15EC**	0	0
Alternative 1 – spider mites	Oberon 2SC	0	0
Alternative 2 – spider mites	Zeal	0	0
Alternative 3 – spider mites	Temik 15G[C]	10	0
Alternative 4 – spider mites	Acramite 4SC	10-15	0

[A] only useful and applicable during the early portion of the season (not the most critical period)

[B] must be tank-mixed with an OP or carbamate to achieve this level of control, applied alone the control would be 30%.

[C] must be applied preventatively so not a remedial product; would not maintain control until the late-season period where quality is compromised

Table 2. VOC producing insecticides: Acres used and rate of application

Chemical name	Trade name	Pest(s) controlled	No. acres treated[a] 2005	2006	2007	Months of appls.	Rate form ac/ appl[b]	% control
Chlorpyrifos	Lorsban 4E	cotton aphid, silverleaf whitefly	390,194	256,692	46,862	June to Oct.	2 pt.	75 (Aphid), 30 (WF)
Oxamyl	Vydate C-LV	cotton aphid, lygus bugs	138,340	92,916	17,903	June to Oct.	34 oz.	70 (aphid), 80 (lygus)
Abamectin	Zephyr 0.15EC	spider mites	320,683	250,327	211,551	May to Aug.	16 oz.	90

[a] Use rates from 2005 to 2007 pesticide use report data.

[b] Formulated amount based on 2005 pesticide use report data i.e. active ingredient/ac modified to formulated amount/ac.

Table 3. Amount (lbs) and percent of total VOC emission produced by active ingredients for 2005 through 2007 in cotton

		2005		2006		2007	
Chemical name	Trade name	Amount[a]	Percent	Amount[a]	Percent	Amount[a]	Percent
Chlorpyrifos	Lorsban 4E	406,473	24.4	287,552	21.2	47,201	7.5
Oxamyl	Vydate C-LV	74,345	4.5	52,836	3.9	9,599	1.5
Abamectin	Zephyr 0.15EC	64,730	3.9	47,273	3.5	37,572	6.0

[a] Amount times 1000 pounds from 2005 to 2007 pesticide use report data and Dept of Pesticide Regulation.

Table 4. Alternative insecticides to Lorsban 4E - Application details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl.[a]	Appl. method	Percent control[b]
Flonicamid	Carbine 50WG	cotton aphid	1	June – Oct.	2.8 oz.	Ground/ Air	90-100
Acetamiprid	Assail 70WP	cotton aphid, silverleaf whitefly	2	June – Oct.	1.1 oz. (aphids), 2.3 oz. (whitefly)	Ground/ Air	80 – 90
Imidacloprid	Provado 1.6F	cotton aphid	1	June – Oct.	3.75 fl. oz.	Ground/ Air	70 – 90
Thiamethoxam	Centric WG	cotton aphid	1	June – Oct.	2 oz.	Ground/ Air	60-70
Chlorpyrifos	Lorsban Advanced	cotton aphid,	2	June – Oct.	2 pts.	Ground/ Air	70 – 90
Aldicarb	Temik 15G[A]	cotton aphid	1	June – Oct.	14 lbs.	Ground	70-80
Buprofezin	Courier 40SC	silverleaf whitefly	1	June – Oct.	12.5 fl. oz.	Ground/ Air	80-90
Spiromesifen	Oberon 2SC	silverleaf whitefly	1	June – Oct.	16 fl. oz.	Ground/ Air	70-80
Dinotefuran	Venom 20SG, Venom 70WG	silverleaf whitefly	1	June – Oct.	3 oz	Ground/ Air	60-80

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Lorsban 4E.

Table 5. Cost of Lorsban 4E and replacement cost of alternative insecticides for Lorsban 4E

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac [a]
Chlorpyrifos	**Lorsban 4E**	**8.65**	**pt**	**2.00**	**Ground/ Air**	**17.30**	**27.30**
Flonicamid	Carbine 50WG	2.80	oz	2.80	Ground/ Air	7.84	16.84
Acetamiprid	Assail 70WP	19.33	oz	1.10 (aphids), 2.30 (whitefly)	Ground/ Air	21.23, 44.46	60.53, 106.92
Imidacloprid	Provado 1.6F	3.74	fl.oz	3.75	Ground/ Air	14.03	23.03
Thiamethoxam	Centric WG	7.30	oz	2.00	Ground/ Air	14.60	23.60
Chlorpyrifos	Lorsban Advanced	8.64	pt	2.00	Ground/ Air	17.28	52.56
Aldicarb	Temik 15G[A]	5.70	lb	14.00	Ground	79.80	88.80
Buprofezin	Courier 40SC	2.63	fl.oz	12.50	Ground/ Air	32.88	41.88
Spiromesifen	Oberon 2SC	4.76	fl.oz	16.00	Ground/ Air	76.16	85.16
Dinotefuran	Venom 20SG, Venom 70WG	10.31	oz	3.00	Ground/ Air	30.93	39.93

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 6. Replacement cost of alternative scenarios for Lorsban 4E

Target pest(s)	Alternative	Trade name	Cost per acre	Percent of Lorsban 4E replacement acreage	Replacement cost[a] 2005	2006	2007
cotton aphid	Alternative 1	Carbine 50WG	16.84	35	2,299,803	1,512,943	276,205
cotton aphid	Alternative 2	Assail 70WP	60.53	23.5	5,549,967	3,651,087	666,547
silverleaf whitefly	Alternative 2	Assail 70WP	106.92	23.5	9,803,909	6,449,574	1,177,442
cotton aphid	Alternative 3	Provado 1.6F	23.03	1	89,842	59,103	10,790
cotton aphid	Alternative 4	Centric WG	23.60	1	92,086	60,579	11,059
cotton aphid, silverleaf whitefly	Alternative 5	Lorsban Advanced	52.56	7	1,435,602	944,421	172,415
cotton aphid	Alternative 6	Temik 15G[A]	88.80	1	346,492	227,942	41,613
Silverleaf whitefly	Alternative 7	Courier 40SC	41.88	4	653,575	429,959	78,494
Silverleaf whitefly	Alternative 8	Oberon 2SC	85.16	2	664,578	437,198	79,815
Silverleaf whitefly	Alternative 9	Venom 20SG, Venom 70WG	39.93	2	311,609	204,994	37,424
				100%	21,247,464	13,977,801	2,551,804
			Lorsban 4E cost		10,262,102	6,751,000	1,232,471
			Difference in cost from change		10,985,362	7,226,801	1,319,334

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 7. Alternative insecticides to Vydate C-LV - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl. [a]	Appl. method	Percent control [b]
Acetamiprid	Assail 70WP	Cotton aphid	1	June – Oct.	1.1 oz.	Ground/ Air	80 – 90
Flonicamid	Carbine 50WG	Cotton aphid, lygus bugs	2	June – Oct.	2.8 oz.	Ground/ Air	80-100
Thiamethoxam	Centric WG	Cotton aphid	1	June – Oct.	2 oz.	Ground/ Air	60-70
Cyfluthrin + Imidacloprid	Leverage 2.7	Cotton aphid, lygus bugs	2	June – Oct.	5 oz.	Ground/ Air	70-80
Chlorpyrifos	Lorsban Advanced	Cotton aphid	1	June – Oct.	2 pts.	Ground/ Air	70–90
Zeta-cypermethrin	Mustang Max	Lygus bugs	1	June – Aug.	3.6 oz	Ground/ Air	80
Acephate	Orthene 75S	Lygus Bugs	1	June – Aug.	1 lbs.	Ground/ Air	80
Imidacloprid	Provado 1.6F	Cotton aphid	1	June – Oct.	3.75 fl. oz.	Ground/ Air	70 – 90
Methidathion	Supracide 25WP	Lygus bugs	1	June – Aug.	4 lbs.	Ground/ Air	40
Aldicarb	Temik 15G[A]	Cotton aphid, lygus bugs	1	June	14 lbs.	Ground	70-80
Lambda-cyhalothrin	Warrior with Zeon, Warrior II	Lygus bugs	2	June – Aug.	3.6 oz.	Ground/ Air	80

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.

[b] Compared to Vydate C-LV.

Table 8. Cost of Vydate C-LV and replacement cost of alternative insecticides for Vydate C-LV

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac [a]
Oxamyl	**Vydate C-LV**	**0.94**	**fl. oz**	**34.0**	**Ground/ Air**	**31.96**	**40.93**
Acetamiprid	Assail 70WP	19.33	oz	1.10	Ground/ Air	21.26	60.53
Flonicamid	Carbine 50WG	6.60	oz	2.80	Ground/ Air	18.48	27.48
Thiamethoxam	Centric WG	7.30	oz	2.00	Ground/ Air	14.60	23.60
Cyfluthrin + Imidacloprid	Leverage 2.7	3.87	fl. oz	5.00	Ground/ Air	19.35	56.70
Chlorpyrifos	Lorsban Advanced	8.64	pt	2.00	Ground/ Air	17.28	52.56
Zeta-cypermethrin	Mustang Max	2.40	fl. oz	3.60	Ground/ Air	8.64	17.64
Acephate	Orthene 75S	15.79	lb	1.00	Ground/ Air	15.79	24.79
Imidacloprid	Provado 1.6F	3.74	fl.oz	3.75	Ground/ Air	14.03	23.03
Methidathion	Supracide 25WP	9.75	lb	4.00	Ground/ Air	39.00	48.00
Aldicarb	Temik 15G[A]	5.70	lb	14.00	Ground	79.80	88.80
Lambda-cyhalothrin	Warrior with Zeon, Warrior II	3.21	fl. oz	3.60	Ground/ Air	11.56	41.11

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 9. Replacement cost of alternative scenarios for Vydate C-LV.

Target Pest(s)	Alternatives	Trade name	Cost per acre	Percent of Vydate C-LV replacement acreage	Replacement cost[a] 2005	2006	2007
Cotton aphid	Alternative 1	Assail 70WP	60.53	30	2,511,950	1,687,150	325,097
Cotton aphid, lygus bugs	Alternative 2	Carbine 50WG	27.48	40	1,520,633	1,021,333	196,801
Cotton aphid	Alternative 3	Centric WG	23.60	1	32,648	21,928	4,225
Cotton aphid, lygus bugs	Alternative 4	Leverage 2.7	56.70	7	549,071	368,784	71,061
Cotton aphid	Alternative 5	Lorsban Advanced	52.56	7	508,981	341,857	65,872
Lygus bugs	Alternative 6	Mustang Max	17.64	4	97,613	65,562	12,633
Lygus Bugs	Alternative 7	Orthene 75S	24.79	1	34,294	23,034	4,438
Cotton aphid	Alternative 8	Provado 1.6F	23.03	1	31,853	21,394	4,122
Lygus bugs	Alternative 9	Supracide 25WP	48.00	1	66,403	44,600	8,594
Cotton aphid, lygus bugs	Alternative 10	Temik 15G[A]	88.80	4	491,384	330,038	63,595
Lygus bugs	Alternative 11	Warrior with Zeon, Warrior II	41.11	4	227,497	152,799	29,443
				100%	6,072,328	4,078,476	785,882
				Vydate C-LV cost	5,666,406	3,805,839	733,348
				Difference in cost from change	405,921	272,637	52,534

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 10 .Alternative insecticides to Zephyr 0.15EC - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl [a]	Appl method	% control [b]
Spiromesifen	Oberon 2SC	spider mite	1	May-Aug.	16 oz.	Ground/ Air	90-100
Etoxazole	Zeal	spider mite	1	May-Aug.	1 oz.	Ground/ Air	90-100
Aldicarb	Temik 15G	spider mite	1	May-Aug.	14 lbs.	Ground	60-80
Bifenazate	Acramite 4SC	spider mite	1	May-Aug.	24 fl. oz.	Ground/ Air	60-80

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Zephyr 0.15EC.

Table 11. Cost of Zephyr 0.15EC and replacement cost of alternative insecticides for Zephyr 0.15EC

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac [a]
Abamectin	**Zephyr 0.15EC**	**7.22**	**fl. oz**	**16.00**	**Ground/ Air**	**115.52**	**124.52**
Spiromesifen	Oberon 2SC	4.76	fl. oz	16.00	Ground/ Air	76.16	85.16
Etoxazole	Zeal	31.42	oz	1.00	Ground/ Air	31.42	40.42
Aldicarb	Temik 15G [A]	5.70	lbs	14.99	Ground	11.40	20.40
Bifenazate	Acramite 4SC	2.11	fl. oz	24.00	Ground/ Air	50.64	59.64

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 12. Replacement cost of alternative scenarios for Zephyr 0.15EC.

Target Pest(s)	Alternatives	Trade name	Cost per acre	Percent of Zephyr 0.15EC replacement acreage	Replacement cost[a] 2005	2006	2007
spider mite	Alternative 1	Oberon 2SC	85.16	48	13,108,495	10,232,567	8,647,528
spider mite	Alternative 2	Zeal	40.42	48	6,221,763	4,856,744	4,104,428
spider mite	Alternative 3	Temik 15G	88.80	3	854,300	666,871	563,572
spider mite	Alternative 4	Acramite 4SC	59.64	1	191,255	149,295	126,169
				100%	20,375,813	15,905,477	13,441,697
			Zephyr 0.15EC cost		39,931,447	31,170,718	26,342,331
			Difference in cost from change		(19,555,634)	(15,265,241)	(12,900,634)

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 13. VOC producing herbicides and alternatives

	Materials	Yield loss (%)	Quality change (%)
VOC Producing Pesticide	**Treflan HFP** [a]	0	0
Alternative 1 –	Prowl H2O	0	0
VOC Producing Pesticide	**Goal 2XL**	0	0
Alternative 1 –	Goal Tender	0	0
Alternative 2 –	ET Herbicide/Defoliant	0	0
Alternative 3 –	Rely 280	0	0
Alternative 4 –	Chateau SW or WDG	0	0
Alternative 5 –	Shark EW	0	0
Alternative 6 –	Karmex DF or XP	0	0
Alternative 7 –	Roundup, Touchdown, etc.	0	0
VOC Producing Pesticide	**Prowl 3.3EC**	0	0
Alternative 1 –	Prowl H2O	0	0

[a] Treflan 4D, Treflan 4EC

Table 14. VOC Producing Herbicides: Acres used and rate of application

Chemical name	Trade name	Pest(s) controlled	No. acres treated[a] 2005	2006	2007	Months of appls.	Rate form ac/appl[b]	% control
Trifluralin	Treflan 4EC+ Others	Grasses, Pigweed, Lambsquarter, Purslane	197,185	159,117	96,308	Feb. – Apr.	1.5 pts.	99
Oxyfluorfen	Goal 2XL	Winter broadleaves, annual morning glory	196,140	126,848	64,823	Jan. – Mar. Jun. – Jul.	2 pts.	75
Pendimethalin	Prowl 3.3EC	Grasses, Pigweed, Lambsquarter, Purslane	103,479	51,896	26,205	Feb. – Apr.	2.4 pts.	99

[a] Use rates from 2005 to 2007 pesticide from Pesticide Use report data, Dept of Pesticide Regulation
[b] Formulated amount based on 2005 pesticide use report data i.e. active ingredient/ac modified to formulated amount/ac.

Table 15. Amount (lbs) and percent of total VOC emission produced by active ingredients for 2005 through 2007 in cotton

Chemical name	Trade name	2005 Amount[a]	2005 Percent	2006 Amount[a]	2006 Percent	2007 Amount[a]	2007 Percent
Trifluralin	Treflan HFP + Others	170,481	10.2	159,551	11.8	94,043	15.0
Oxyfluorfen	Goal 2XL	136,060	8.2	117,559	8.7	69,525	11.1
Pendimethalin	Prowl 3.3EC	126,570	7.6	65,252	4.8	33,397	5.3

[a] Amount from 2005 to 2007 from Pesticide Use report data, Dept of Pesticide Regulation.

Table 16. Alternative herbicides to Treflan HFP[a] - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl.[b]	Appl. method	Percent control[c]
Pendimethalin	Prowl H2O	grasses, pigweed, lambsquarter, purslane	1	Feb. - Apr.	3 pts.	Ground/ Air	99%

[a] Treflan 4D, Treflan 4EC, Treflan 4L

[b] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.

[c] Compared to Treflan HFP.

Table 17. Cost of Treflan HFP and replacement cost of alternative herbicides for Treflan HFP

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac[a]
Trifluralin	**Treflan HFP**	**4.85**	**pt**	**1.50**	**Ground/ Air**	**7.28**	**16.28**
Pendimethalin	Prowl H2O	7.01	pt	3.00	Ground/ Air	21.03	30.03

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 18. Replacement cost of alternative scenarios for Treflan HFP.

Target Pest(s)	Alternatives	Trade name	Cost per acre	Percent of Treflan HFP replacement acreage	Replacement cost[a] 2005	2006	2007
Grasses, pigweed, lambsquarter, purslane	Alternative 1	Prowl H2O	30.03	100	26,491,835	26,882,015	23,186,974
				100%	26,491,835	26,882,015	23,186,974
				Treflan HFP cost	14,357,463	14,568,924	12,566,367
				Difference in cost from change	12,134,372	12,313,091	10,620,607

Table 19. Alternative herbicides to Goal 2XL - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl [a]	Appl method	% control [b]
Oxyfluorfen	Goal Tender	Winter fallow beds - broadleaf weeds, Annual morning glory	1.3	Jan. – Mar. Jun. – Jul.	1 pt.	Ground/ Air	70
Pyraflufen-ethyl	ET Herbicide/ Defoliant	Winter fallow beds - broadleaf weeds, Annual morning glory	1.3	Jan. – Feb. Jun. – Jul.	1 fl oz.	Ground/ Air	70-80
Glufosinate	Rely 280	Winter fallow beds - broadleaf weeds, Annual morning glory	1.3	Jan. – Feb. Jun. – Jul.	29 fl oz.	Ground/ Air	80-90
Flumioxazin	Chateau SW or WDG	Winter fallow beds - broadleaf weeds, Annual morning glory	1.3	Jan. – Feb. Jun. – Jul.	2 oz.	Ground/ Air	75
Carfentrazone	Shark EW	Winter fallow beds - broadleaf weeds, Annual morning glory	1.3	Jan. – Mar. Jun. – Jul.	1.6 fl oz.	Ground/ Air	70-80
Diuron	Karmex DF or XP	In crop only annual morning glory	1.3	Jun. – Jul.	2 lbs.	Ground/ Air	75
Glyphosate	Roundup, Touchdown, etc.	Grasses and some broadleaves	1.3	Jan. – Feb. Mar. – Jul.	2 pts.	Ground/ Air	70 – 90

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Goal 2XL.

Table 20. Cost of Goal 2XL and replacement cost of alternative herbicides for Goal 2XL

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac [a]
Oxyfluorfen	**Goal 2XL**	**17.25**	**pt**	**2.00**	**Ground/ Air**	**34.50**	**56.55**
Oxyfluorfen	Goal Tender	34.98	pt	1.00	Ground/ Air	34.98	57.17
Pyraflufen-ethyl	ET Herbicide/ Defoliant	4.17	fl. oz	1.00	Ground/ Air	4.17	17.12
Glufosinate	Rely 280	0.85	fl. oz	29.00	Ground/ Air	24.65	43.75
Flumioxazin	Chateau SW or WDG	8.47	oz	2.00	Ground/ Air	16.94	33.72
Carfentrazone	Shark EW	9.08	fl. oz	1.60	Ground/ Air	14.53	30.59
Diuron	Karmex DF or XP	7.23	lb	2.00	Ground/ Air	14.46	30.50
Glyphosate	Roundup or Touchdown	13.83	pt	2.00	Ground/ Air	27.66	47.66

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 21. Replacement cost of alternative scenarios for Goal 2XL.

Target Pest(s)	Alternatives	Trade name	Cost per acre	Percent of Goal 2XL replacement acreage	Replacement cost[a] 2005	2006	2007
Broadleaf weeds, morning glory	Alternative 1	Goal Tender	57.17	4	4,077,622	4,336,854	3,691,830
Broadleaf weeds, morning glory	Alternative 2	ET Herbicide/ Defoliant	17.12	9	2,747,388	2,922,051	2,487,453
Broadleaf weeds,	Alternative 3	Rely 280	43.75	2	1,559,936	1,659,108	1,412,348
Broadleaf weeds, morning glory	Alternative 4	Chateau SW or WDG	33.72	5	3,006,296	3,197,419	2,721,864
Broadleaf weeds, morning glory	Alternative 5	Shark EW	30.59	20	10,907,037	11,600,443	9,875,101
Morning glory	Alternative 6	Karmex DF or XP	30.50	10	5,437,757	5,783,458	4,923,280
Grasses, some broadleaf weeds	Alternative 7	Roundup or Touchdown	47.66	50	42,486,821	45,187,886	38,467,059
				100%	70,222,858	74,687,218	63,578,935
				Goal 2XL cost	100,827,971	107,238,027	91,288,439
				Difference in cost from change	30,605,113	32,550,809	27,709,504

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 22. Alternative herbicides to Prowl 3.3EC - Application details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl.[a]	Appl. method	Percent control[b]
Pendimethalin	Prowl H2O	grasses, pigweed, lambsquarter, purslane	1	Feb. – Apr.	3 pts.	Ground/Air	99%

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Prowl 3.3EC

Table 23. Cost of Prowl 3.3EC and replacement cost of alternative herbicides for Prowl 3.3EC

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac [a]
Pendimethalin	**Prowl 3.3EC**	**6.41**	**pt**	**2.40**	**Ground/ Air**	**15.38**	**24.38**
Pendimethalin	Prowl H2O	7.01	pt	3.00	Ground/ Air	21.03	30.03

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 24. Replacement cost of alternative scenarios for Prowl 3.3EC

Target pest(s)	Alternative	Trade name	Cost per acre	Percent of Prowl 3.3EC replacement acreage	Replacement cost[a] 2005	2006	2007
Grasses, pigweed, lambsquarter, purslane	Alternative 1	Prowl H2O	30.03	100	9,789,780	11,754,373	17,241,694
				100%	9,789,780	11,754,373	17,241,694
			Prowl 3.3EC cost		7,949,184	9,544,410	14,000,049
			Difference in cost from change		1,840,596	2,209,963	3,241,645

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Grapes

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California produces over 85% of the grapes in the United States. Grapes are ranked second in value of all California agricultural commodities. Production is distributed among fresh market/table, raisin and wine grapes. Grapes are produced on over 789,000 bearing acres (National Agricultural Statistics Service USDA 2007) with a gross value of $3.08 billion. In 2007, raisin grapes accounted for approximately $600 million, table grapes for $623 million and wine grapes for $1,835 million. There are four major areas of production in the state; these include the southern San Joaquin Valley, northern San Joaquin Valley and Sacramento Valley, coastal and desert. The southern San Joaquin Valley region produces 99% of California's raisin crop, 91% of table grape production and about 60% of the wine grape crop. Coastal areas account for about 19% of the state's wine grape production with roughly half being produced in the north coast region.   Grape production in the northern San Joaquin and Sacramento Valleys focuses almost exclusively on wine grapes with about 20% of the state's wine grape production.   The desert (Coachella Valley) produces 9% of the State's table grapes. About 99% of the nation's commercially grown table grapes are grown in California on approximately 110,000 acres. Since 2000, production has ranged from 678,000 to 872,000 tons of packed grapes (National Agricultural Statistics Service USDA 2007) with about 30% of those being exported each year. Commercial table grapes are primarily grown in regions of California having warm, dry climates.

The San Joaquin, Sacramento and Coachella Valleys are hot, dry interior valleys while the coastal region is cool with higher humidity. Climate differences influence pest problems and crop management options. Two arthropod pests that drive the monitoring schedule during the field season are leafhoppers and mites (Flaherty et al. 1992). Western grape leafhopper, *Erythroneura elegantula*, is a pest on grapes north of Tehachapi Mountains; it is not found in the Coachella Valley. Variegated leafhopper, *Erythroneura variabilis*, is the major pest of grapes in southern California and in the Central Valley as far north as San Joaquin County. The Pacific spider mite, *Tetranychus pacificus*, is the primary pest mite throughout the State. Willamette spider mite, *Eotetranychus willamettei*, is a pest in the Central

and North Coast and the Sierra Foothill production areas. In addition, mealybugs have become a growing problem in recent years due in part to the introduction of new exotic species and in part to the discovery that they transmit some of the grape leafroll viruses (Godfrey et al. 2002; Golino et al. 2002). Grape mealybug, *Pseudococcus maritimus*, and obscure mealybug, *Pseudoccus viburni*, occur throughout the State. Longtailed mealybug, *Pseudococcus longispinus*, is primarily a pest in Southern Central Coast. Vine mealybug, *Pseudococcus ficus*, was detected in the Coachella Valley in the early 1990s. It then spread throughout the southern San Joaquin Valley and is now found in isolated vineyards in the North and Central Coast and the Sacramento Valley.
Sharpshooters have also risen in importance with the introduction of glassy-wing sharpshooter, *Homalodisca vitripennis*, because they can vector the bacteria *Xylella fastidiosa,* which causes Pierce's disease (Varela et al. 2001).

Weed control in vineyards enhances the establishment of newly planted vines and improves the growth and yield of established vines. Weeds reduce vine growth and yields by competing for water, nutrients and sunlight (Smith et al. 2008). Competition is most severe during the first 4 years of the vine's life or where root growth is limited. Also, plants on the vineyard floor can influence other pests such as insects, mites, nematodes and diseases. Weeds around the grapevine trunk compete directly with vine growth, but also provide a good habitat for voles and gophers that can girdle and kill young vines (Ingels et al. 2005). There are a variety of chemical and cultural control practices that can be employed against weeds (Hembree et al 2006). Weed management varies considerably due to climatic conditions, soils, irrigation practices, topography, grape crop, and grower preferences. Weeds are commonly controlled either chemically or with cultivation in a 2 to 5 feet wide strip in the vine row. The area between vine rows may be chemically treated, mechanically mowed or tilled. Cultivation is not recommended for vineyards planted in hillsides due to the potential for erosion. Also, cultivation may increase compaction at 4 to 7 inches deep. In most vineyards, herbicides are used only on a narrow strip of soil centered on the vineyard row; thus, the area treated with herbicides in these vineyards is 15 to 30% of the total vineyard area. Glyphosate is a widely used, common post-emergent herbicide. However, this practice is changing due to resistance (Shrestha et al. 2007).

Early research on gibberellin for use on grapes revolutionized the table fruit industry by significantly increasing the size of seedless grapes (Coombe 1960; Harrell and Williams 1987). Since the introduction of gibberellins for commercial use, domestic demand for table grapes has shifted from seeded to seedless cultivars, and today 71% of American consumers prefer seedless grapes (Crisosto and Crisosto 2002). More than fifty varieties of table grapes (California Table Grape Commission) are grown in California and of those approximately 65% are seedless and require some amount of gibberellin applied to improve berry size and fruit quality. Gibberellin is also applied to some seeded varieties, such as 'Redglobe' and 'Emperor,' to improve uniformity of berry size within the bunch and reduce berry shrivel.

California Department of Pesticide Regulation (DPR) has identified a number of pesticides used on grapes as emitting volatile organic compounds (VOC) and contributing to air quality problems in California. DPR is concentrating its efforts on pesticides with an emission potential (EP) of greater than 20%. Grapes are the eleventh (wine) and twelfth (raisin and fresh market) largest VOC contributors of all agricultural commodities. However the combination of wine, raisin and fresh market contributed 1,574,600 lbs of VOC-producing materials from emulsifiable concentration formulations in 2007. Thus the grape total accounts for the second largest VOC contributor of all agricultural commodities. The top four VOC producing pesticides used in grapes and non-VOC producing alternate pesticides or formulations (Table 1) are discussed with regard to pest control activity and IPM potential**.**

Insecticides

Chlorpyrifos – Lorsban 4E, with an EP value of 39, is used to control several insect pests. It is an efficacious product for ant and mealybug (grape, obscure, longtailed and vine mealybugs) control. Lorsban 4E is also used to control black widow spiders in table grapes (Table 2). Chlorpyrifos was applied at 135,786, 145,679 and 170,083 lbs of active ingredient (ai) to 66,870, 76,082 and 86,031 acres of vineyards from 2005 to 2007, respectively (California Department of Pesticide Regulation, 2005, 2006 and 2007). Since there are 789,000 bearing acres of grapes, approximately 20% of all vineyards are treated with Lorsban 4E and on average 2 lb ai/acre of chlorpyrifos or 4 pt of Lorsban 4E/acre was used per application. The VOC emissions of Lorsban 4E has increased slightly from 10.5% in 2005 to 12.5% in 2007 of the total VOC emissions of chemicals used on grapes (Table 3).

In other crops chlorpyrifos is registered as Lorsban 50W and Lorsban 75WG, both with low emission potential. However these formulations are not registered for use on grapes and no studies have been conducted on how effective these formulations would be for mealybug or ant control. Recently, Lorsban Advanced 3.76WE (EP value of 18) received a 24c emergency registration for mealybug and ant control. This 24c registration only allows applications before budbreak for mealybug control. Although delay dormant application is the best timing for vine mealybug in southern California counties (Daane et al. 2006) and for grape, obscure, and longtailed mealybugs (Flaherty 1992), this timing is not recommended for vine mealybug in northern California counties. In northern California, vine mealybug is hidden under the bark at or below the graft union during delay dormant to during budbreak. Unless all the bark is removed from the vine, this timing is not effective and is not recommended for vineyards in northern California. The best timing for controlling vine mealybug in northern California with Lorsban is immediately after harvest if harvest occurs before mid-October.

There are a number of low EP alternative insecticides for the control of mealybugs (Bentley et al. 2002, Varela 2008a). The most effective include buprofezin (Applaud 70WP – EP of 2) and spirotetramat (Movento – EP not available) (Table 4). Applaud is an insect growth regulator, thus is limited to the control of the crawler stage and young nymphs. Movento is a very efficacious systemic product that needs to be applied to the foliage from about mid-April or later. However, the EPA has suspended the registration of Movento because of a technical problem. Thus, Movento will probably not be available for the 2010 growing season. It is hoped the registration will be reinstated in the near future.

There are also systemic insecticides such as Admire Pro (imidacloprid), Platinum (thiamethoxam) and Venom (dinotefuran). For these systemic insecticides, the amount of uptake by the plant depends on soil properties. Admire Pro is effective for mealybug control in the light soils of the San Joaquin and Coachella Valleys as well as areas in the Central Coast, however it does not work in the heavy clay soils common to many coastal areas and some areas of the Sacramento Valley. Venom and Platinum are newly registered products and their efficacy in different soil types is under study (Varela 2008b). At the registered rate of 1.1 oz, Assail gives incomplete control. However, a higher rate of Assail is currently under review by the EPA.

In 2006, ant bait stations were registered for Argentine ant control. Gourmet Ant Bait (1% borate solution) and Vitis Liquid Ant Bait (0.001% imidacloprid) were recently registered for placing in the bait stations. Research on these baits is still ongoing and efficacy is still being evaluated. Baits are slow-acting, taking 2 to 3 years before producing a noticeable drop in ant populations. Thus, the only available alternative to Lorsban 4E for a quick knock-down of ant populations is Lorsban Advanced 3.76WE. Control of honeydew harvesting ants is important to allow natural enemies to control honeydew-producing pests such as mealybugs and European fruit lecanium scale.

Control of black widow spiders is only needed in vineyards growing table grapes for export due to quarantine restrictions. The delayed-dormant use of Lorsban Advanced for mealybug is the most effective and least disruptive control for black widow adults. In season, Lannate 90SP can be used as a low VOC-producing substitute for Lorsban 4E.

All low VOC alternatives have a higher cost per acre than Lorsban 4E (Table 5). The total cost (product + application costs) of Lorsban 4E is $34.50 per acre, while alternatives range from $38.88 for Lorsban Advanced to $60.00 for Movento per acre. Assuming that the acreage receiving Lorsban 4E is replaced by 80% with Lorsban Advanced, 10% with Applaud and 10% with Movento, we estimate that a complete substitution for Lorsban 4E with low VOC products would have been $440,272, $500,924, and $566,428 in additional costs, based on treated acreages in 2005, 2006, and 2007, respectively (Table 6). This would increase insecticide cost by $6.58 per acre or 19% (Table 6).

Herbicides

Oxyfluorfen – Goal 2XL, with an EP of 39, is a nonselective pre- and post-emergent broadleaf herbicide. Approximately 1/3 of the grape acreage receives an oxyfluorfen application, with acres treated fluctuating between 254,000 to 283,000 from 2005 to 2007 (Table 2). Oxyfluorfen formulated as Goal 2XL accounts for between 20.7 to 23.6% of the total emissions from grapes (Table 3). Goal 2XL is commonly applied as a post-emergent herbicide following harvest up to February 15. Higher rates are needed for long-term residual control. It is often combined with glyphosate to increase efficacy on various broadleaf weeds and grass species. Oxyfluorfen is commonly used because it is an effective pre- and post-emergent herbicide for many difficult-to-control weeds such as malva (*Malva* spp.), burning nettle (*Urtica urens)*, purslane (*Portulaca oleracea)* and fillaree (*Erodium* spp). The herbicide is generally applied one time in the fall or winter months for annual weed control in vineyard rows. A new formulation of oxyfluorfen (GoalTender®) with an EP value of 5 has recently been registered as an alternative to the Goal 2XL. Substituting GoalTender for Goal 2XL would eliminate the VOC issues and provide equivalent weed control. The new formulation of GoalTender herbicide provided comparable control to most of the same weeds as Goal 2XL, as shown in experiments conducted in California (T. Lanini, unpublished data)

Simazine which has an EP of 1 when formulated as a wettable powder (Princep Caliber 90) or an EP of 9 when formulated as a liquid (Princep 4L), may substitute for Goal 2XL. They control many of the same weed species as oxyfluorfen. GoalTender or a combination of GoalTender and Simazine, Princep 4L and Caliber 90, would replace Goal 2XL with equivalent control with a decrease in cost (Tables 7, 8 and 9). Simazine is considered to be a groundwater contaminant and requires a use permit within Ground Water Protection Areas.

All low VOC alternatives have a lower cost per acre than Goal 2XL (Table 8). The total cost (product + application costs) of Goal 2XL is $47.82 per acre, while alternatives range from $44.04 for GoalTender to $20.18 for Princep Caliber 90 per acre. Assuming that the acreage receiving Goal 2XL is replaced by 80% with GoalTender, 10% with Princep 4L and 10% with Princep Caliber 90, we estimated that a complete substitution for Goal with low VOC products would be $2,185,088, $2,304,847, and $2,075,438 in reduced costs, based on treated acreages in 2005, 2006, and 2007, respectively (Table 9). This would be a decrease in herbicide cost by about $8.15 per acre or 17% (Table 9).

Oryzalin – The liquid formulation of oryzalin, Surflan A.S., has an EP of 39. Surflan A.S. was applied to less than 5% of the State's vineyard acreage with total treated acreage of 33,000, 46,000 and 26,000 in 2005, 2006 and 2007, respectively. Oryzalin formulated as Surflan A.S. accounts for 3.8 to 5.2% of the total emissions from grapes (Table 3). Oryzalin is applied at 2 qt per acre as a pre-emergent herbicide in the vineyard strip one time per season. This product is a pre-emergence selective herbicide most effective on annual grass species and numerous broadleaf annuals. It is used to maintain control in strips down the vineyard row. It is often used in combination with other pre-emergence herbicides. An alternative for use in vineyards to the emulsifiable formulation (Surflan A.S.) is simazine, which has an EP of 1 when formulated as a wettable powder (Princep Caliber 90) or an EP of 9 when formulated as a liquid (Princep 4L). Simazine controls many of the weeds controlled by oryzalin, but does not control several important grasses or field bindweed seedlings, which are controlled by oryzalin. Simazine is considered to be a groundwater contaminant and requires a use permit within Ground Water Protection Areas.

All low VOC alternatives have a lower cost per acre than Surflan A.S. (Table 11). The total cost (product + application costs) of Surflan A.S. is $48.68 per acre, while alternatives range from $24.01 for Princep 4L to $20.18 for Princep Caliber 90 per acre. Assuming that the acreage receiving Surflan A.S. is replaced by 30% with Princep 4L and 70% with Princep Caliber 90, we estimate that a complete substitution for Surflan A.S. with low VOC products would have been $899,556, $1,256,199 and $710,345 in reduced costs, based on treated acreages in 2005, 2006, and 2007, respectively (Table 12). This would be a decrease in herbicide costs of about $27.00 per acre or 56% (Table 9).

Plant Growth Regulators

Gibberellic Acid – The form of gibberellin manufactured for grape production is GA_3, commonly called gibberellic acid. Gibberellic acid is applied during three phenological stages of grapevine growth (pre-bloom, bloom, fruit set) to improve the quality of table and raisin grapes and the size and uniformity of table grapes. Applications made before bloom, termed stretch sprays, are thought to loosen bunches by elongating the rachis and lateral lengths of the cluster. Applications made during the 30 to 90 percent bloom stage stimulate flower abscission and reduce berry set. Fruit set applications significantly increase the size of seedless grapes. Modern commercial table grape production would be impossible without the use of gibberellic acid. The number of applications and application rates vary for each variety, ranging from a single application at 0.4 grams/acre to multiple applications up to 208 grams/acre, per season.

The gibberellic acid formulation commonly marketed for use on grape is a 4% solution (96% isopropanol). The solution contains approximately one gram of active ingredient per one fluid ounce of formulated product. The liquid formulation is popular among grape growers because it is easy to measure and use, especially when recommended rates are very low (≤ 1 gram/acre). However, the liquid formulations have very high emission potential (EP) values (>92%) because of their isopropanol solvents. Gibberellic acid is also available to grape growers in soluble powder and granular formulations, with EP values are 4% or less.

Gibberellin was applied to 197,418, 176,066 and 188,829 acres from 2005, 2006 and 2007 respectively (Table 2). Gibberellin, formulated as 4% solution, accounts for about 10% of the total emissions from grapes (Table 3). There are several alternatives for Gibberellin 4% solution (Falgro 4L, Gibgro 4LS, ProGibb 4%), including Gibro 20% Powder, ProGibb Plus 2X, ProGibb 40% and Gibro 5% Powder. The total cost (product + application costs) of Falgro 4L, Gibgro 4LS or ProGibb 4% is $198.00 per acre while alternatives range in the cost from $208.00 for Gibgro 5% powder to $198.00 for ProGibb 40% (Table 14).

Assuming that the acreage treated with 4% solution of Gibberellin is replaced with 17.5% Gibgro 20% Powder, 17.5% ProGibb Plus 2X, 60% ProGibb 40% and the remaining 5% is replaced with Gibgro 5% Powder, we estimate that there would be a 40% increase in cost (Table 15). Complete substitution of 4% solution of Gibberellin with low VOC products would have been $236,902, $211,279, and $226,595 in additional costs, based on treated acreages in 2005, 2006, and 2007, respectively or about $1.20 per acre increased cost to the grower (Table 15).

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Tables

Table 1. VOC Producing Pesticides and Alternatives

	Materials	Yield loss (%)	Quality change
VOC Producing Pesticide	**Lorsban 4E**	0	
Alternative 1	Lorsban Advanced		None
Alternative 2	Applaud 70DF		None
Alternative 3	Movento		None
VOC Producing Pesticide	**Goal 2XL**	0	
Alternative 1	GoalTender		None
Alternative 2	Princep 4L		None
Alternative 3	Princep Caliber 90		None
VOC Producing Pesticide	**Surflan AS**	0	
Alternative 1	Princep 4L		None
Alternative 2	Princep Caliber 90		None
VOC Producing Pesticide	**4% liquid concentrate gibberellic acid formulations**	0	
Alternative 1	Gibgro 20% Powder		None
Alternative 2	ProGibb Plus 2X		None
Alternative 3	ProGibb 40%		None
Alternative 4	Gibgro 5% Powder		None

Table 2. VOC Producing Pesticides - Application Details

Chemical name	Trade name	Pest(s) controlled	No. acres treated[a] 2005	2006	2007	Months of appls.	Rate form ac/ appl[b]	% control
Chlorpyrifos	Lorsban 4E	Mealybug (MB), Argentine ant (AA), Black Widow Spider (BWS)	66,870	76,082	86,031	Feb.-March, Sept.-Oct.	4 pt/ac	90
Oxyfluorfen	Goal 2XL	Broadleaf weeds	268,030	282,720	254,580	Dec. – Feb.	2.36 pt/ac	> 80
Oryzalin	Surflan AS	Broadleaf and grass weeds	32,955	46,020	26,023	Dec. – Feb.	2.00 qt/ac	> 80
Gibberellic Acid	Falgro 4L, Gibgro 4LS, ProGibb 4%	Increase cluster length, reduce berry set, reduce hand-thinning costs, increase berry size and uniformity, reduce berry shrivel	197,418	176,066	188,829	May – Jun.	23 g/ac	> 90

[a] From 2005, 2006 and 2007 pesticide use report data, respectively.

[b] Formulated amount based on average of 2005-07 pesticide use report data (active ingredient/ac modified to formulated amount/ac).

Table 3. Amount (lbs) and percent of total VOC emission produced by active ingredients for 2005 through 2007 in grapes

		2005		2006		2007	
Chemical name	Trade name	Amount[a]	Percent	Amount[a]	Percent	Amount[a]	Percent
Chlorpyrifos	Lorsban 4E	156,332	10.1	169,284	11.1	197,595	12.5
Oxyfluorfen	Goal 2XL	361,755	23.4	359,405	23.6	325,478	20.7
Oryzalin	Surflan AS	59,306	3.8	79,915	5.2	65,124	4.1
Gibberellic Acid	Falgro 4L,Gibgro 4LS,ProGibb 4%	152,289	9.8	136,385	8.9	152,733	9.7

[a] Amount times 1000 pounds from 2005 to 2007 pesticide use report data.

Table 4. Alternative insecticides to Lorsban 4E - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Formulated Rate/ac[a]	Appl. method	Percent control[b]
Chlorpyrifos	Lorsban Advanced	MB, AA, BWS	1	Feb-March.	4.0 pt/ac	Ground	100
Buprofezin	Applaud 70DF	MB	1	March-June.	12.0 oz/ac	Ground	100
Spirotetramat	Movento	MB	1	May-June.	6.0 fl.oz/ac	Ground	100

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Lorsban 4E.

Table 5. Cost of Lorsban 4E and replacement cost of alternative insecticides for Lorsban 4E

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac [a]
Chlorpyrifos	Lorsban 4E	6.40	pt	4.0	Ground	25.60	34.60
Chlorpyrifos	Lorsban Advanced	7.47	pt	4.0	Ground	29.88	38.88
Buprofezin	Applaud 70DF	2.65	oz	12.0	Ground	31.80	40.80
Spirotetramat	Movento	8.50	fl.oz	6.0	Ground	51.00	60.00

[a] Application cost of ground speed sprayer is $ 9.00 /ac.

Table 6. Replacement cost of alternative scenarios for Lorsban 4E

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Lorsban 4E replacement acreage	Replacement cost[a] 2005	2006	2007
MB, AA, BWS	Alternative 1	Lorsban Advanced	38.88	80	2,079,924	2,366,455	2,675,908
MB	Alternative 2	Applaud 70DF	40.80	10	272,830	310,415	351,006
MB	Alternative 3	Movento	60.00	10	401,220	456,492	516,186
			Total	100%	2,753,974	3,133,361	3,543,101
			Cost of Lorsban 2E		2,313,702	2,632,437	2,976,673
			Difference in cost from change[b]		440,272	500,924	566,428

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs.

Table 7. Alternative herbicides to Goal 2XL - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Formulated rate/ac [a]	Appl method	Percent control [b]
Oxyfluorfen	GoalTender	Broadleaf weeds	1	Oct. – Feb.	1.00 pt/ac	Ground/chemig	> 99%
Simazine	Princep 4L	Broadleaf & grass weeds	1	Oct. – Feb.	2.50 qt/ac	Ground	> 80%
Simazine	Princep Caliber 90	Broadleaf & grass weeds	1	Oct. – Feb.	2.20 lb/ac	Ground	> 80%

[a] Most use rates based on 2005 pesticide use report data, i.e. active ingredient/ac modified to formulated amount/ac.
[b] Compared to Goal 2XL.

Table 8. Cost of Goal 2XL and replacement costs of alternative herbicides to Goal 2XL

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl method [a]	Total material cost/ac	Total material & appl. cost/ac [a]
Oxyfluorfen	Goal 2XL	16.45	pt	2.36	Ground	38.82	47.82
Oxyfluorfen	GoalTender	35.04	pt	1.00	Ground	35.04	44.04
Simazine	Princep 4L	6.08	qt	2.50	Ground	15.20	24.20
Simazine	Princep Caliber 90	5.08	lb	2.20	Ground	11.18	20.18

[a] Application cost of ground speed sprayer is $9.00 /ac.

Table 9. Replacement cost of alternative scenarios for Goal 2XL

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Goal 2XL replacement acreage	Replacement cost[a] 2005	2006	2007
Broadleaf weeds	Alternative 1	GoalTender	44.04	80	9,443,233	9,960,791	8,969,363
Broadleaf & grass weeds	Alternative 2	Princep 4L	24.20	10	648,633	684,182	616,084
Broadleaf & grass weeds	Alternative 3	Princep Caliber 90	20.18	10	540,777	570,416	513,641
				100%	10,632,643	11,215,389	10,099,087
			Cost of Goal 2XL		12,817,731	13,520,236	12,174,525
			Difference in cost from change[b]		(2,185,088)	(2,304,847)	(2,075,438)

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs.

Table 10. Alternative herbicides to Surflan A.S. - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Formulated Rate/ac[a]	Appl method	Percent control[b]
Simazine	Princep 4L	Broadleaf & grass weeds	1	Oct. – Feb.	2.5 qt/ac	Ground	> 80%
Simazine	Princep Caliber 90	Broadleaf & grass weeds	1	Oct. – Feb.	2.2 lb/ac	Ground	> 80%

[a] Most use rates based on 2005 pesticide use report data, i.e. active ingredient/ac modified to formulated amount/ac.
[b] Compared to Surflan A.S.

Table 11. Cost of Surflan A.S. and replacement costs of alternative herbicides to Surflan A.S.

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl method [a]	Total material cost/ac	Total material & appl. cost/ac [a]
Oryzalin	Surflan A.S.	19.84	qt	2.0	Ground	39.68	48.68
Simazine	Princep 4L	6.08	qt	2.5	Ground	15.20	24.20
Simazine	Princep Caliber 90	5.08	lb	2.2	Ground	11.18	20.18

[a] Application cost of ground speed sprayer is $ /ac.

Table 12. Replacement cost of alternative scenarios for Surflan A.S.

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Surflan A.S. replacement acreage	Replacement cost[a] 2005	2006	2007
Broadleaf weeds	Alternative 1	Princep 4L	24.20	30	239,253	334,105	188,926
Broadleaf weeds	Alternative 2	Princep Caliber 90	20.18	70	465,430	649,949	367,528
				100%	704,683	984,054	556,455
			Cost of Surflan A.S.		1,604,249	2,240,254	1,266,800
			Difference in cost from change[b]		(899,556)	(1,256,199)	(710,345)

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs.

Table 13. Alternative to Falgro 4L, Gibgro 4LS, ProGibb 4% - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Formulated Rate/ac[a]	Appl method	% control[b]
Gibberellins	Gibgro 20% Powder	Increase cluster length, reduce berry set, reduce hand-thinning costs, increase berry size and uniformity, reduce berry shrivel	1	May-June	100 g/ac	Ground	100
Gibberellins	ProGibb Plus 2X		1	May-June	100 g/ac	Ground	100
Gibberellins	ProGibb 40%		1	May-June	50 g/ac	Ground	100
Gibberellins	Gibgro 5% Powder		1	May-June	400 g/ac	Ground	100

[a] Most use rates based on 2005 pesticide use report data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Falgro 4L, Gibgro 4LS, ProGibb 4%.

Table 14. Cost of Falgro 4L, Gibgro 4LS, ProGibb 4% and replacement costs of alternative gibberellins

Chemical name	Trade name	Cost	Unit	Ave. Formulated Rate/ac	Appl method[a]	Total material cost/ac	Total material & appl. cost/ac[a]
Gibberellins	Falgro 4L, Gibgro 4LS, ProGibb 4%	1.68	g	20	Ground	134.00	198.00
Gibberellins	Gibgro 20% Powder	0.34	g	100	Ground	136.00	200.00
Gibberellins	ProGibb Plus 2X	0.34	g	100	Ground	136.00	200.00
Gibberellins	ProGibb 40%	0.67	g	50	Ground	134.00	198.00
Gibberellins	Gibgro 5% Powder	0.09	g	400	Ground	144.00	208.00

[a] Application cost of ground speed sprayer is $16.00 /ac.

Table 15. Replacement cost of alternative scenarios for Falgro 4L, Gibgro 4LS, ProGibb 4%

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Falgro 4L, Gibgro 4LS, ProGibb 4% replacement acreage	Replacement cost[a] 2005	2006	2007
Increase cluster length, berry size & uniformity, reduce berry set & berry shrivel	Alternative 1	Gibgro 20% Powder	200.00	17.5	6,909,630	6,162,310	6,609,015
Same as above	Alternative 2	ProGibb Plus 2X	200.00	17.5	6,909,630	6,162,310	6,609,015
Same as above	Alternative 3	ProGibb 40%	198.00	60.0	23,453,258	20,916,641	22,432,885
Same as above	Alternative 4	Gibgro 5% Powder	208.00	5.0	2,053,147	1,831,086	1,963,822
				100%	39,325,666	35,072,347	37,614,737
			Cost of Falgro 4L, etc.		39,088,764	34,861,068	37,388,142
			Difference in cost from change[b]		236,902	211,279	226,595

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs.

Lettuce

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California produces about 290,000 acres of lettuce consisting of head lettuce, which is of declining importance and the leaf lettuces, which are of increasing importance (NASS 2008). California produces over 70% of the head 'Iceberg' lettuce in the United States. Head lettuce is grown on over 135,000 acres and is concentrated in three areas of the state: coast region, southern San Joaquin Valley and lower desert region. The coast region produces the majority of the state's crop, about 75%. The southern San Joaquin Valley is the second largest producer of head lettuce with over 23,000 acres. Production there is limited to the cooler spring and fall months. Finally, the lower desert region of California produces head lettuce briefly during the winter months on about 20,000 acres. California produces about 78% of the leaf lettuce grown in the United States. The leaf lettuce crop is made up mostly of romaine lettuce (60%), followed by green leaf (24%), red leaf (11%) and butterhead lettuce (6%). These varieties are grown mostly within the three primary growing regions. The coast region is the leading producer of leaf lettuce and produces crops year round. The lower desert region produces only a winter crop of leaf lettuce, but contributes a significant portion of the total state crop. The San Joaquin Valley produces leaf lettuce briefly in the spring and again in the fall, and its contribution to the state's total production is minimal. Leaf lettuce is generally produced for fresh market; however, a significant portion of the romaine and butterhead varieties was processed as packaged salad mixes and shredded for the fast food market (Ryder 1999; UC-VRIC 1996).

High quality standards for head lettuce mean that growers must be inordinately cautious of insect and disease pest outbreaks. Feeding damage, crop contamination and transmission of disease are common results if insect pests are not monitored and managed appropriately. The high quality standards that apply to head lettuce also apply to leaf lettuce. In addition, a similar array of insect pests damage both leaf and head lettuce, thus requiring frequent applications of pesticides. California Department of Pesticide Regulation (DPR) has identified a number of pesticides used on lettuce as contributing volatile organic compounds (VOC) to air quality problems in California. DPR is proposing to regulate pesticides with evaporate potentials (EP) of greater than 20%. Leaf and head lettuce combined are the third largest VOC contributor of agricultural commodities from emulsifiable concentrate formulations and contributed over 217,000 lbs of VOC producing materials in 2005. The top six VOC producing pesticides and their non-VOC producing alternative pesticides or formulations are discussed with regard to pest control activity and IPM potential. Because of their similarities, head and leaf lettuce are combined for this discussion.

Insecticides

Dimethoate – Dimethoate E267 and other EC formulations, with EP levels exceeding 20%, are used in head lettuce for control of various aphid species, especially for the lettuce aphid (*Nasonovia ribis-nigri*), foxglove aphid (*Aulacorthum solani*) and the lettuce root aphid (*Pemphigus bursarius*). Dimethoate is also used to manage the green peach aphid (*Myzus persicae*) and the potato aphid (*Macrosiphum euphorbiae*). There have been reports of tolerance to and lack of good control of the various aphid species by Dimethoate. There are a number of low EP alternatives to Dimethoate such as imidacloprid (Admire Pro, Alias 2F and Provado 1.6F), acetamiprid (Assail 70WP) and pymetrozine (Fulfill) with EP values ranging from 1 to 4 (Table 1). These products are effective in controlling the aphid species (Polumbo, 2001; Polumbo et al., 2001; Polumbo, 2002; Polumbo, 2006). Dimethoate was applied to 60,920, 70,660 and 30,237 acres in 2005, 2006 and 2007, respectively (Table 2). The large decrease in the use of Dimethoate is the result of effective alternatives and decreased insecticide use in 2007. There was a corresponding decrease in the amount of VOC produced by Dimethoate from 28,200 lbs in 2005 to 11,200 lbs in 2007 with the percent of total non-fumigant produced decreasing from 5.2% to 1.9% (Table 3). The use rate of the alternatives was based on the 2006 PUR data. The alternatives Provado 1.6F, Assail 70WP and Fulfill are estimated to require two applications to provide equivalent control to Dimethoate while only one application of Admire Pro and Alias 2F would be required to provide equivalent control to Dimethoate (Table 4). The material cost and application of the alternatives was estimated to range from approximately $60 to about $90 per acre (Table 5). For 2005-2007, the elimination of Dimethoate E267 and other EC formulations of dimethoate would have increased costs to lettuce growers from $1,975,164 to $4,6615,706 or about $65.30 per acre (Table 6).

Permethrin – Pounce 3.2EC, with an EP value of 51, is the most commonly used pesticide on lettuce and the most commonly used formulation of permethrin. Pounce 3.2EC is used primarily to manage lepidopterous pests of lettuce which include the cutworms (*Agrotis ipsilon, Peridroma saucia,* and *Feltia subterranean*), beet armyworm (*Spodoptera exigua*), cabbage looper (*Trichoplusia ni*), alfalfa looper (*Autographa california*), corn earworm (*Heliocoverpa zea*) and tobacco budworm (*Heliothis virescens*) (Table 1). Permethrin is also used to control field crickets (*Gryllus* spp.) and darkling beetles in seedling lettuce. Permethrin is also produced in a 25% wettable powder formulation (Pounce 25WP/Ambush 25WP) with EP values of 2 to 3. There are several alternative insecticides that are superior to permethrin that can be used to manage lepidopterous pests of lettuce. They are as follows: spinosad (Success 2SC) with an EP value of 4, tebufenozide (Confirm 2F) with an EP value of 7, methoxyfenozide (Intrepid 2F) with an EP value of 5, thiodicarb (Larvin 3.2) with an EP value of 5, indoxacarb (Avaunt 70DG) with an EP value of 4, and emamectin benzoate (Proclaim 5WG) with an EP value of 1. Spinosad is probably the best of lepidopterous insecticides registered for use on lettuce. Proclaim 5WG is registered for use only on head lettuce. Carbaryl (Sevin) bait 5% with an EP value of 2 is available for use to control cutworm species, darkling beetles and field crickets in lettuce. *Bacillus thuringiensis* is also available to manage loopers and beet armyworms in lettuce. Pounce 3.2EC was applied to 25,447, 50,421 and 51,486 acres in 2005, 2006 and 2007, respectively (Table 2). The amount of VOC produced by Pounce 3.2 EC was approximately 10,000 lbs and accounted for 1.5% of the total non-fumigant produced on lettuce (Table 3). The use rate of the alternatives was based on the 2006 PUR data. The alternatives Confirm 2F and Intrepid 2F are estimated to require two applications to provide equivalent control to Pounce 3.2EC while only one application for all other alternatives would be required for equivalent control to Pounce 3.2EC (Table 7). The material and application cost was estimated to range from approximately $18 to about $70 per acre (Table 8). The $70 per acre amount was for Entrust, which would only be used by organic growers and thus the costs are somewhat higher than would be expected. The elimination of Pounce 3.2 EC would have increased costs to lettuce growers in the period of 2005 – 2007 from $548,220 to $1,109,194 or about $21.50 per acre (Table 9).

Lambda-cyhalothrin – Warrior, with an EP value of 30, is a pyrethroid with a mode of action similar to that of Pounce 3.2EC and cypermethrin (Ammo 2.5EC), an is used to control lepidopterous pests in lettuce. There are numerous insecticides such as Success 2SC, Confirm 2F, Intrepid 2F, Larvin 3.2, Avaunt 70DG and Proclaim 5WG that are good alternatives for control of lepidopterous pests in lettuce. Warrior was applied to 89,198, 145,284 and 144,945 acres in 2005, 2006 and 2007, respectively (Table 2). Despite the relatively large number of acres treated with Warrior as compared to the other VOC producing insecticides, the amount of VOC produced was only approximately 11,000 lbs and accounted for 2.0% of the total non-fumigant produced on lettuce (Table 3). The use rate of the alternatives was based on the 2006 PUR data. The alternatives Confirm 2F and Intrepid 2F are estimated to require two applications to provide equivalent control to Warrior while only one application for all other alternatives would be required for equivalent control to Warrior (Table 10). The material and application cost was estimated to range from approximately $26 to about $70 per acre (Table 11). The $70 per acre amount was for Entrust, which would only be used by organic growers and thus the costs are somewhat higher than would be expected. The elimination of Warrior would have increased costs to lettuce growers in the period of 2005 – 2007 from $3,098,560 to $5,046,876 or about $34.75 per acre (Table 12).

Oxydemeton-methyl – Metasystox-R, with an EP value of 59, is also used in lettuce for control of various aphid species. An increased usage of Metasystox-R is due to the invasion of the foxglove aphid to California lettuce. The neonicotinoid insecticides, such as Admire Pro, Alias 2F, Provado 1.6F and Assail 70WP, and the pymetronine Fulfull provide excellent alternatives to Metasystox-R for control of the aphid species. Metasystox-R was applied to 56,836, 54,258 and 55,906 acres in 2005, 2006 and 2007, respectively (Table 2). Despite the relatively small number of acres treated with Metasystox-R as compared to other VOC producing insecticides, the amount of VOC produced was 96,175 , 98,065 and 102,182 lbs or 2005, 2006 and 2007, respectively. This amount of VOC accounted for about 17.3% of the total non-fumigant produced on lettuce (Table 3). The use rate of the alternatives was based on the 2006 PUR data. The alternatives Provado 1.6F, Assail 70WP and Fulfill are estimated to require two applications to provide equivalent control to Metasystox-R while only one application of Admire Pro and Alias 2F would be required for equivalent control to Metasystox-R (Table 13). The material cost and application was estimated to range from approximately $65 to about $95 per acre (Table 14). The elimination of Metasystox-R would have increased costs to lettuce growers in the period of 2005 – 2007 from $2,341,178 to $2,452,417 or about $43.15 per acre (Table 15).

Diazinon – Diazinon is produced in numerous emulsifiable concentrate formulations such as Diazinon AG500 and others, with EP values ranging from 39 to 44. Diazinon is also produced in wettable powder formulations (such as Diazinon 50W and Diazinon 14G) with EP values of 2 to 5, and granule formulations with EP values of 3 to 5. Diazinon 14G is used to control seedling pests of lettuce such as garden symphylans (*Scutigerella immaculata*), springtails and darkling beetles. Various Diazinon formulations are recommended for green peach aphid and potato aphid control. The neonicotinoid insecticides, Admire Pro, Alias 2F, Provado 1.6 F and Assail 70 WP, provide superior control compared to Diazinon for green peach aphid and potato aphid in lettuce. Fulfill can also be used to control the aphid species. Diazinon was the most widely used VOC producing insecticides on lettuce and was applied to 79,914, 175,201 and 185,276 acres in 2005, 2006 and 2007, respectively (Table 2). Also, Diazinon accounts for the largest amount of VOC produced on lettuce. Diazinon produced 102,800 lbs and 120,400 lbs of VOCs for 2005 and 2007, respectively, and accounted for about 20.0% of the total non-fumigant produced on lettuce (Table 3). The use rate of the alternatives was based on the 2006 PUR data. The use rate of Provado 1.6F, Assail 70WP and Fulfill was estimated to require two applications to provide equivalent control to Diazinon while only one application for all other alternatives would be required for equivalent control to Diazinon (Table 16). The material and application cost was estimated to range from approximately $16.0 to about $95 per acre (Table 17). The elimination of Diazinon would have increased costs to lettuce growers in the period of 2005 – 2007 from $4,421,022 to $10,249,885 or about $55.30 per acre (Table 18).

Herbicides

Lettuce seeds are planted 1.75 to 3 inches apart in rows on 40-inch beds. Lettuce is thinned to 9 to 12 inch spacing in the rows by hand hoeing crews. Weeds that are present at time of lettuce thinning are also removed. Major herbicides used in lettuce are pronamide (Kerb 50W) and bensulide (Prefar 4E) and both are old products having been registered in the 1960s and 1970s (Fennimore and Doohan 2008). Pre-emergence herbicides, such as Kerb 50W or Prefar, are typically applied as a 5 to 6 inch wide band over the seed lines after planting prior to the first irrigation. Physical weed control tools include mechanical cultivation and hand weeding. Lettuce is thinned and weeded approximately 30 days following planting, and then an additional hand weeding is carried out 2 to 3 weeks later. Thinning and hand weeding costs for lettuce are approximately $250 per acre (Meister 2004).

Weeds are among the most common pests of vegetable crops and present a constant obstacle to profitable vegetable production. Herbicides available to vegetable growers are few in number and those few do not control all weeds. Therefore, vegetable crops almost always require hand weeding and cultivation to maintain cost-effective weed control. Uncontrolled weeds in vegetables result in lower yields, reduced quality, and decreased harvest efficiency, particularly in hand-harvested crops such as lettuce. Lettuce and tomato are very susceptible to weed competition. Weed cover of 25% resulted in 20 to 40% yield loss in California lettuce, and >25% weed cover resulted in complete yield loss (Lanini and LeStrange, 1991). Weed competition for over 4 weeks resulted in yield loss (Fennimore and Umeda 2005).

To meet the needs of the market, lettuce is planted every day of the year in the spring and summer coastal region or the winter desert production region.. As a result of this geographical and seasonal variation, weed spectrum varies considerably. In the coastal areas, nearly all of the weeds are broadleaf weeds, and as a result the post-emergence grass herbicides such as clethodim and sethoxydim are seldom used and are of little value. Common weeds in the coastal areas are shepherd's-purse (*Capsella bursa pastoris*), burning nettle (*Urtica urens*) and purslane (*Portulaca oleracea*). Common weeds in the San Joaquin Valley and desert production areas would be purslane, barnyardgrass (*Echinocloa crus-galli*) and junglerice (*Echinocloa colonum*). Weeds such as pigweeds (*Amaranthus* spp.) and nettleleaf goosefoot (*Chenopodium murale*) can be found in all areas.

Kerb 50W is the most important lettuce herbicide and it controls most of the commonly found lettuce weeds, but does not control important weeds such as little mallow (*Malva parviflora*), pigweeds and sowthistle (*Sonchus* spp.). Prefar controls a very narrow weed spectrum, but does provide excellent control of pigweeds and purslane, and for this reason is often applied in mixture with Kerb 50W to broaden the weed control spectrum. Benefin (Balan DF) is primarily a grass herbicide and is most important in the desert production areas where grass weeds are more common. In the coastal production areas Balan DF is not used very often as grass weeds are not common and the rotational restrictions for Balan DF are much longer than for Kerb 50W or Prefar 4E. Spinach is commonly grown in rotation with lettuce, but is very sensitive to herbicides used in the rotational crop. The plantback restriction for spinach following Balan DF is 10 months, compared to 4 months for Prefar 4E and 3 to 7 months for Kerb 50W.

Bensulide – Prefar 4E, with an EP value of 39, is widely used in lettuce for control of grass and broadleaf weeds. Prefar 4E was applied to 15,823 and 18,064 acres of head lettuce and 21,463 and 29,467 acres of leaf lettuce for 2005 to 2007, respectively (Tables 20a and 20b). Prefar 4E was responsible for 12.8% to 22.7% of all VOC produced on lettuce during 2005 and 2007 (Table 21). It is particularly effective in controlling common purslane (*Portulaca oleracea*) and pigweeds (*Amaranthus* spp.) in the summer and is used in the cooler part of the year to provide control of burning nettle (*Urtica urens*) (Table 22). A low EP alternative herbicide is pronamide (Kerb 50W) but as of August 3, 2009, Kerb 50WP is only labeled for head lettuce and can no longer be used on leaf lettuce. Kerb 50W has an EP value of 2 and has been widely used in lettuce, but its use will be more limited in the future. Control of burning nettle with Kerb 50W is very good while control of purslane is generally better when applied with Prefar 4E. There are other bensulide formulations that have low EP values and they should be tested as alternatives to Prefar 4E and registered in lettuce. Prefar controls pigweed, but Kerb 50W does not. The only alternative for pigweed control in lettuce is Balan DF. However the 10-month plantback restrictions for rotational crops following Balan DF make its use problematic in coastal areas where carrot, onion, and spinach are grown as rotational crops. Because of the rotational restrictions, it is difficult to see how Balan DF can replace Prefar 4E on the central coast. In head lettuce, the elimination of Prefar 4E would have increased costs to lettuce growers in the period of 2005 – 2007 from $847,638 to $966,894 or about $10.45 per acre (Table 21a).

The loss of Kerb 50W for use in leaf lettuce has serious implications. If Prefar cannot be used owing to VOC regulations and Kerb 50W is no longer registered for leaf lettuce, then Balan would be the only herbicide available for leaf lettuce. It is estimated that leaf lettuce producers on the coast who are unable to use Prefar 4E or Kerb 50W would see drastic increased weeding costs. Hand weeding would cost the grower approximately $300 per acre, since most producers would choose to not use Balan DF owing to rotational restrictions and poor weed control. The elimination of Prefar 4E would have increased costs to lettuce growers in the period of 2005 – 2007 from $2,895,490 to $4,031,264 or about $134.91 per acre (Table 24b). Because >90% of California lettuce is direct seeded there are no ready alternatives to Kerb 50W or Prefar. A switch to lettuce transplants would allow for the registration of new herbicides, such as pendimethalin and S-metolachlor. However, these herbicides are not registered and switching from direct seeded lettuce to transplants would increase the production cost per acre by >$200 per acre (Richard Smith, UCCE Monterey personal communication).

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Tables

Table 1. VOC Producing Insecticides and Alternatives

	Materials	Yield loss (%)	Quality Change
VOC Producing Insecticide	**Dimethoate E267**	0	
Alternative 1	Admire Pro		None
Alternative 2	Alias 2F		None
Alternative 3	Provado 1.6F		None
Alternative 4	Assail 70WP		None
Alternative 5	Fulfill		None
VOC Producing Insecticide	**Pounce 3.2EC**	0	
Alternative 1	Pounce 25WP		None
Alternative 2	Ambush 25WP		None
Alternative 3	Success 2SC		None
Alternative 4	Entrust		None
Alternative 5	Confirm 2F		None
Alternative 6	Intrepid 2F		None
Alternative 7	Larvin 3.2		None
Alternative 8	Avaunt 70DG		None
Alternative 9	Proclaim 5WG		None
VOC Producing Insecticide	**Warrior**	0	
Alternative 1	Success 2SC		None
Alternative 2	Entrust		None
Alternative 3	Confirm 2F		None
Alternative 4	Intrepid 2F		None
Alternative 5	Larvin 3.2		None
Alternative 6	Avaunt 70DG		None
Alternative 7	Proclaim 5WG		None

VOC Producing Insecticide	**Metasystox-R**	0	
Alternative 1	Admire Pro		None
Alternative 2	Alias 2F		None
Alternative 3	Provado 1.6F		None
Alternative 4	Assail 70WP		None
Alternative 5	Fulfill		None
VOC Producing Insecticide	**Diazinon AG 500**	0	
Alternative 1	Admire Pro		None
Alternative 2	Alias 2F		None
Alternative 3	Provado 1.6F		None
Alternative 4	Assail 70WP		None
Alternative 5	Fulfill		None
Alternative 6	Diazinon 50W		None

Table 2. VOC Producing Insecticides – Application Details - Head and leaf lettuce combined

		Pest(s)	No. acres treated[a]			Months of		
Chemical name	Trade name	controlled	2005	2006	2007	applis.	Rate form ac/appl[b]	% control
Dimethoate	Dimethoate E267	Aphids[2]	85,806	70,660	30,237	Year around	12.0 oz/ac	>80
Permethrin	Pounce 3.2EC	Lep. larvae[1]	49,139	50,421	51,486	Year around	6.0 oz/ac	>80
Lambda-cyhalothrin	Warrior II	Lep. larvae	167,604	145,284	144,945	Year around	1.7 oz/ac	>80
Oxydemeton-Methyl	Metasystox-R	Fox glove aphid	56,845	54,258	55,906	Year around	1.8 pt/ac	>80
Diazinon	Diazinon AG 500	Green peach aphid and potato aphid	172,881	175,201	185,276	Year around	1.2 pt/ac	>80

[a] Use rates from 2005 to 2007 pesticide use report data.
[b] Formulated amount based on 2005 pesticide use report data i.e. active ingredient/ac modified to formulated amount/ac.

Table 3. Amount (lbs) and percent of total non-fumigant emission produced by active ingredients for 2005 through 2007 in lettuce

		2005		2006		2007	
Chemical name	Trade name	Amount	Percent	Amount	Percent	Amount	Percent
Dimethoate	Dimethoate E267	28.2	5.2	23.6	4.0	11.2	1.9
Permethrin	Pounce 3.2EC	10.1	1.9	10.3	1.7	8.0	1.4
Lambda-cyhalothrin	Warrior	11.8	2.2	10.5	1.8	11.5	2.0
Oxydemeton-methyl	Metasystox-R	96.2	17.9	98.1	16.5	102.2	17.6
Diazinon	Diazinon AG 500	102.8	19.1	119.8	20.1	120.4	20.7

[a] Amount times 1000 pounds from 2005 to 2007 pesticide use report data and Dept of Pesticide Regulation.

Table 4. Alternative insecticides to Dimethoate E267

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/appl[b]	Appl. method	% control
Imidacloprid	Admire Pro	Aphids[2]	1	At planting	7.00 fl.oz/ac	Soil	90
Imidacloprid	Alias 2F	Aphids	1	At planting	16.00 fl.oz/ac	Soil	90
Imidacloprid	Provado 1.6F	Aphids	2	After sprouting	3.80 fl.oz/ac	Foliar	80
Acetameprid	Assail 70WP	Aphids	2	After sprouting	1.30 oz/ac	Foliar	80
Pymetrozine	Fulfill	Aphids	2	After sprouting	2.75 oz/ac	Foliar	80

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.

[b] Compared to Dimethoate E267.

Table 5. Cost of Dimethoate E267 and replacement cost of alternative insecticides for Dimethoate E267

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac [a]
Imidacloprid	Admire Pro	11.40	fl.oz	7.00	Soil	79.80	88.80
Imidacloprid	Alias 2F	4.44	fl.oz	16.00	Soil	71.04	80.04
Imidacloprid	Provado 1.6F	5.47	fl.oz	3.80	Foliar	41.57	59.57
Acetameprid	Assail 70WP	19.33	oz	1.30	Foliar	50.26	68.26
Pymetrozine	Fulfill	8.49	oz	2.75	Foliar	46.70	64.70

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 6. Replacement cost of alternative scenarios for Dimethoate E267

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Dimethoate E267 replacement acreage	Replacement cost[a]		
					2005	2006	2007
Aphids	Alternative 1	Admire Pro	88.80	35	2,666,850	2,196,113	939,766
Aphids	Alternative 2	Alias 2F	80.04	35	2,403,769	1,979,469	847,059
Aphids	Alternative 3	Provado 1.6F	59.57	10	511,164	420,936	180,128
Aphids	Alternative 4	Assail 70WP	68.26	10	585, 695	482,311	206,392
Aphids	Alternative 5	Fulfill	64.70	10	555,122	457,135	195,618
			Total	100%	6,722,600	5,535,964	2,368,963
			Cost of Dimethoate E267		1,117,516	920,258	393,799
			Difference in cost from change		5,605,084	4,615,706	1,975,164

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 7. Alternative insecticides to Pounce 3.2EC

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/appl[b]	Appl. method	% control
Permethrin	Pounce 25WP	Lep. larvae[1]	1	Year around	9.60 oz/ac	Foliar	>90
Permethrin	Ambush 25W	Lep. larvae	1	Year around	9.60 oz/ac	Foliar	>90
Spinosad	Success 2SC	Lep. larvae	1	Year around	6.00 fl.oz/ac	Foliar	>90
Spinosad	Entrust	Lep. larvae	1	Year around	1.80 oz/ac	Foliar	>90
Tebufenozide	Confirm 2F	Lep. larvae	2	Year around	7.00 fl.oz/ac	Foliar	>90
Methoxyfenozide	Intrepid 2F	Lep. larvae	2	Year around	7.00 fl.oz/ac	Foliar	>90
Thiodicarb	Larvin 3.2	Lep. larvae	1	Year around	23.00 fl.oz/ac	Foliar	>90
Indoxacarb	Avaunt 70DG	Lep. larvae	1	Year around	4.20 oz/ac	Foliar	>90
Emamectin benzoate	Proclaim 5WG	Lep. larvae	1	Year around	3.60 oz/ac	Foliar	>90

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.

[b] Compared to Pounce 3.2EC.

Table 8. Cost of Pounce 3.2EC and replacement cost of alternative insecticides for Pounce 3.2EC

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac[a]
Permethrin	Pounce 25WP	0.99	oz	9.60	Foliar	9.50	18.50
Permethrin	Ambush 25W	0.89	oz	9.60	Foliar	8.54	17.54
Spinosad	Success 2SC	7.00	fl.oz	6.00	Foliar	42.00	51.00
Spinosad	Entrust	33.68	oz	1.80	Foliar	60.62	69.62
Tebufenozide	Confirm 2F	2.24	fl.oz	7.00	Foliar	31.36	49.36
Methoxyfenozide	Intrepid 2F	2.96	fl.oz	7.00	Foliar	41.44	59.44
Thiodicarb	Larvin 3.2	0.74	fl.oz	23.00	Foliar	17.02	26.02
Indoxacarb	Avaunt 70DG	7.46	oz	4.20	Foliar	31.33	40.33
Emamectin benzoate	Proclaim 5WG	11.03	oz	3.60	Foliar	39.71	48.71

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 9. Replacement cost of alternative scenarios for Pounce 3.2EC

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Pounce 3.2EC replacement acreage	Replacement cost[a] 2005	2006	2007
Lep. larvae	Alternative 1	Pounce 25WP	18.50	20	181,854	186,598	190,539
Lep. larvae	Alternative 2	Ambush 25W	17.54	10	86,209	88,459	90,327
Lep. larvae	Alternative 3	Success 2SC	51.00	10	250,609	257,147	262,579
Lep. larvae	Alternative 4	Entrust	69.62	10	342,125	351,051	358,466
Lep. larvae	Alternative 5	Confirm 2F	49.36	10	242,550	248,878	254,135
Lep. larvae	Alternative 6	Intrepid 2F	59.44	10	292, 082	299,702	306,033
Lep. larvae	Alternative 7	Larvin 3.2	26.02	10	127, 860	131,195	133,967
Lep. larvae	Alternative 8	Avaunt 70DG	40.33	10	198,187	203,358	207,653
Lep. larvae	Alternative 9	Proclaim 5WG	48.71	10	239, 346	245,591	250,778
			Total	100%	1,960,823	2,011,979	2,054,477
			Cost of Pounce 3.2EC		902,192	925,730	945,283
			Difference in cost from change		1,058,631	1,086,250	1,109,194

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs

Table 10. Alternative insecticides to Warrior

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/appl[b]	Appl. method	% control
Spinosad	Success	Lep. larvae[1]	1	Year around	6.00 fl.oz/ac	Foliar	>90
Spinosad	Entrust	Lep. larvae	1	Year around	1.80 oz/ac	Foliar	>90
Tebufenozide	Confirm 2F	Lep. larvae	2	Year around	7.00 fl.oz/ac	Foliar	>90
Methoxyfenozide	Intrepid 2F	Lep. larvae	2	Year around	7.00 fl.oz/ac	Foliar	>90
Thiodicarb	Larvin 3.2	Lep. larvae	1	Year around	23.00 fl.oz/ac	Foliar	>90
Indoxacarb	Avaunt 70DG	Lep. larvae	1	Year around	4.20 oz/ac	Foliar	>90
Emamectin benzoate	Proclaim 5WG	Lep. larvae	1	Year around	3.60 oz/ac	Foliar	>90

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.

[b] Compared to Warrior.

Table 11. Cost of Warrior and replacement cost of alternative insecticides for Warrior

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac[a]
Spinosad	Success	7.00	fl.oz	6.00	Foliar	42.00	51.00
Spinosad	Entrust	33.68	oz	1.80	Foliar	60.62	69.62
Tebufenozide	Confirm 2F	2.24	fl.oz	7.00	Foliar	31.36	49.36
Methoxyfenozide	Intrepid 2F	2.96	fl.oz	7.00	Foliar	41.44	59.44
Thiodicarb	Larvin 3.2	0.74	fl.oz	23.00	Foliar	17.02	26.02
Indoxacarb	Avaunt 70DG	7.46	oz	4.20	Foliar	31.33	40.33
Emamectin benzoate	Proclaim 5WG	11.03	oz	3.60	Foliar	39.71	48.71

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 12. Replacement cost of alternative scenarios for Warrior

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Warrior replacement acreage	Replacement cost[a] 2005	2006	2007
Lep. larvae	Alternative 1	Success	51.00	14.29	1,221,115	1,058,498	1,056,028
Lep. larvae	Alternative 2	Entrust	69.62	14.29	1,667,037	1,445,036	1,441,664
Lep. larvae	Alternative 3	Confirm 2F	49.36	14.29	1,181,848	1,024,460	1,022,069
Lep. larvae	Alternative 4	Intrepid 2F	59.44	14.29	1,423,197	1,233,669	1,230,790
Lep. larvae	Alternative 5	Larvin 3.2	26.02	14.29	623,008	540,041	538,781
Lep. larvae	Alternative 6	Avaunt 70DG	40.33	14.29	965,686	837,085	835,132
Lep. larvae	Alternative 7	Proclaim 5WG	48.71	14.29	1,166,237	1,010,928	1,008,569
			Total	100%	8.248.128	7,149,716	7,133,033
			Cost of Warrior		2,425,900	2,102,841	2,097,934
			Difference in cost from change		5,822,228	5,046,876	5,035,099

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 13. Alternative insecticides to Metasystox-R

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/appl[b]	Appl. method	% control
Imidacloprid	Admire Pro	Aphids[2]	1	At planting	7.50 fl.oz/ac	Soil	90
Imidacloprid	Alias 2F	Aphids	1	At planting	16.00 fl.oz/ac	Soil	90
Imidacloprid	Provado 1.6F	Aphids	2	After sprouting	3.80 fl.oz/ac	Foliar	80
Acetameprid	Assail 70WP	Aphids	2	After sprouting	1.30 oz/ac	Foliar	80
Pymetrozine	Fulfill	Aphids	2	After sprouting	2.75 oz/ac	Foliar	80

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.

[b] Compared to Metasystox-R.

Table 14. Cost of Metasystox-R and replacement cost of alternative insecticides for Metasystox-R

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac [a]
Imidacloprid	Admire Pro	11.40	fl.oz	7.50	Soil	85.50	94.50
Imidacloprid	Alias 2F	4.44	fl.oz	16.00	Soil	71.04	80.04
Imidacloprid	Provado 1.6F	5.47	fl.oz	3.80	Foliar	41.57	59.57
Acetameprid	Assail 70WP	19.33	oz	1.30	Foliar	50.26	68.26
Pymetrozine	Fulfill	8.49	oz	2.75	Foliar	46.70	64.70

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 15. Replacement cost of alternative scenarios for Metasystox-R

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Metasystox-R replacement acreage	Replacement cost[a] 2005	2006	2007
Aphids	Alternative 1	Admire Pro	94.50	35	1,880,148	1,794,583	1,849,091
Aphids	Alternative 2	Alias 2F	80.04	35	1,592,456	1,519,984	1,566,151
Aphids	Alternative 3	Provado 1.6F	59.57	10	338,637	323,226	333,043
Aphids	Alternative 4	Assail 70WP	68.26	10	388, 013	370,354	381,603
Aphids	Alternative 5	Fulfill	64.70	10	367,759	351,022	361,684
			Total	100%	4,567,013	4,359,169	4,491,572
			Cost of Metasystox-R		2,114,208	2,017,991	2,079,284
			Difference in cost from change		2,452,805	2,341,178	2,412,288

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 16. Alternative insecticides to Diazinon AG 500

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/appl[b]	Appl. method	% control
Imidacloprid	Admire Pro	Aphids[2]	1	At planting	7.50 fl.oz/ac	Soil	90
Imidacloprid	Alias 2F	Aphids	1	At planting	16.00 fl.oz/ac	Soil	90
Imidacloprid	Provado 1.6F	Aphids	2	After sprouting	3.80 fl.oz/ac	Foliar	80
Acetameprid	Assail 70WP	Aphids	2	After sprouting	1.30 oz/ac	Foliar	80
Pymetrozine	Fulfill	Aphids	2	After sprouting	2.75 oz/ac	Foliar	80
Diazinon	Diazinon 50W	Aphids	1	After sprouting	0.75 fl.oz/ac	Foliar	90

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Diazinon AG500.

Table 17. Cost of Diazinon AG 500 and replacement cost of alternative insecticides for Diazinon AG 500

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac[a]
Imidacloprid	Admire Pro	11.40	fl.oz	7.50	Soil	85.50	94.50
Imidacloprid	Alias 2F	4.44	fl.oz	16.00	Soil	71.04	80.04
Imidacloprid	Provado 1.6F	5.47	fl.oz	3.80	Foliar	41.57	59.57
Acetameprid	Assail 70WP	19.33	oz	1.30	Foliar	50.26	68.26
Pymetrozine	Fulfill	8.49	oz	2.75	Foliar	46.70	64.70
Diazinon	Diazinon 50W	9.29	lb.	0.75	Foliar	6.97	15.97

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 18. Replacement cost of alternative scenarios for Diazinon AG 500

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Diazinon AG 500 replacement acreage	Replacement cost[a] 2005	2006	2007
Aphids	Alternative 1	Admire Pro	108.75	30	4,901,176	4,966,948	5,252,575
Aphids	Alternative 2	Alias 2F	97.80	30	4,151,219	4,206,926	4,448,847
Aphids	Alternative 3	Provado 1.6F	59.03	10	1,029,887	1,043,707	1,103,726
Aphids	Alternative 4	Assail 70WP	56.66	10	1,180, 051	1,195,887	1,264,657
Aphids	Alternative 5	Fulfill	64.70	10	1,118,454	1,133,463	1,198,643
Aphids	Alternative 6	Diazinon 50W	15.97	10	276,048	279,752	295,839
				100%	12.656,834	12,826,684	13,564,288
			Cost of Diazinon AG500		3,092,668	3,134,171	3,314,402
			Difference in cost from change		9,564,166	9,692,514	10,249,885

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

[1] **Lep. larvae commonly attacking lettuce include:**

alfalfa looper	*Autugrapha californica*
beet armyworm	*Spodoptera exigua*
cabbage looper	*Trichoplusia ni*
cutworms	*Agrotis ipsilon*
granulate cutworm	*Feltia subterranea*
corn earworm	*Helicoverpa zea*
tobacco budworm	*Heliothis virescens*

[2] **Aphids commonly attacking lettuce include:**

foxglove aphid	*Aulacorthum solani*
green peach aphid	*Myzus persicae*
lettuce root aphid	*Pemphigus bursarius*
lettuce aphid	*Nasonovia ribis-nigri*
potato aphid	*Macrosiphum euphorbiae*

Table 19. VOC Producing Herbicides and Alternatives

	Materials	Yield loss (%)	Quality Change
VOC Producing Pesticide(s)	**Prefar4E**	0%	None
Alternative 1	Kerb 50W	0%	None
Alternative 2	Balan DF	0%	None
Alternative 3	Poast	0%	None
Alternative 4	Kerb 50W + Balan DF	0%	None

Table 20a. VOC Producing Herbicides – Application Details - Head lettuce

Chemical name	Trade name	Pest(s) controlled	No. acres treated[a] 2005	2006	2007	Months of applis.	Rate form ac/appl[b]	% control
Bensulide	Prefar4E	Purslane,	15,836	18,513	18,064	Year-round	1.40 gal/ac	80
		Burning nettle,						50
		Pigweed,						80
		Barnyardgrass						80

[a] Use rates from 2005 to 2007 pesticide use report data.

[b] Formulated amount based on 2005 pesticide use report data i.e. active ingredient/ac modified to formulated amount/ac.

Table 20b. VOC Producing Herbicides – Application Details - Leaf lettuce

Chemical name	Trade name	Pest(s) controlled	No. acres treated[a] 2005	2006	2007	Months of applis.	Rate form ac/appl[b]	% control
Bensulide	Prefar4E	Purslane,	21,463	29,882	29,467	Year-round	1.40 gal/ac	80
		Burning nettle,						50
		Pigweed,						80
		Barnyardgrass						80

[a] Use rates from 2005 to 2007 pesticide use report data.

[b] Formulated amount based on 2005 pesticide use report data i.e. active ingredient/ac modified to formulated amount/ac.

Table 21. Amount (lbs) and percent of total non-fumigant emission produced by active ingredients for 2005 through 2007 in lettuce

Chemical name	Trade name	2005 Amount	2005 Percent	2006 Amount	2006 Percent	2007 Amount	2007 Percent
Bensulide	Prefar4E	102.3	19.0	135.4	22.7	122.8	21.1

[a] Amount times 1000 pounds from 2005 to 2007 pesticide use report data and Dept. of Pesticide Regulation.

Table 22. Alternative Herbicides to Prefar4E

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/appl[b]	Appl. method	% control
Pronamide	Kerb 50W	Purslane	1	Year-round	1.2 lb/ac	ground	90
		Nettle					90
		Pigweed					10
		Barnyardgrass					90
Benefin	Balan DF	Purslane	1	Year-round	1.25 lb/ac	ground	80
		Nettle					10
		Pigweed					80
		Barnyardgrass					80
Sethoxydim	Poast	Purslane	1	Year-round	0.18 gal/ac	ground	0
		Nettle					0
		Pigweed					0
		Barnyardgrass					95
Pronamide +	Kerb 50W +	Purslane	1	Year-round	1.2 lb/ac	ground	95
Benefin	Balan DF	Pigweed			1.25 lb/ac		85
		Barnyardgrass					95

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Prefar 4E.

Table 23. Cost of Prefar4E and replacement cost of alternative herbicides for Prefar4E

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac[a]
Pronamide	Kerb 50W	50.31	lb	1.20	ground	43.47	52.47
Benefin	Balan DF	14.80	lb	1.250	ground	30.83	39.83
Sethoxydim	Poast	103.85	gal	0.18	ground	12.46	21.46

[a]Application cost of ground speed sprayer is $9.00/ac.

Table 24a. Replacement cost of alternative scenarios for Prefar 4E in head lettuce

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Prefar4E replacement acreage	Replacement cost[a] 2005	2006	2007
Purslane only	Alternative 1	Kerb 50W	52.47	10	83,088	97,134	94,778
		Balan DF	39.83	10	63,080	73,743	71,955
Nettle Only	Alternative 2	Kerb 50W	52.47	10	83,088	97,134	94,778
		Balan DF	39.83	10	63,080	73,743	71,955
Pigweed	Alternative 3	Balan DF	39.83	10	63,080	73,743	71,955
Barnyardgrass	Alternative 4	Kerb 50W	52.47	3.33	27,696	32,378	31,593
		Balan DF	39.83	3.33	21,027	24,581	23,985
		Poast	21.46	3.33	11,329	13,244	12,923
Purslane + nettle	Alternative 5	Kerb 50W	52.47	10	83,088	97,134	94,778
Purslane + pigweed	Alternative 6	Balan D	39.83	10	63,080	73,743	71,955
Purslane + pigweed + barnyardgrass	Alternative 7	Kerb 50W+ Balan DF	90.30	20	286,002	334,349	326,240
			Total	100%	847,638	990,927	966,894
			Cost of Prefar		682,063	797,362	778,024
			Difference in cost from change		165,575	193,565	188,870

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 24b. Replacement cost of alternative scenarios for Prefar4E in leaf lettuce

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Prefar4E replacement acreage	Replacement cost[a] 2005	2006	2007
Purslane only	Alternative 1	Hand weed	300.00	10	643,890	896,460	884,010
		Balan DF	39.83	10	85,494	119,030	117,377
Nettle only	Alternative 2	Hand weed	300.00	10	643,890	896,460	884,010
		Balan DF	39.83	10	85,494	119,030	117,377
Pigweed only	Alternative 3	Balan DF	39.83	10	85,494	119,030	117,377
Barnyardgrass	Alternative 4	Hand weed	300.00	3.33	214,630	298,820	294,670
		Balan DF	39.83	3.33	85,494	39,677	39,126
		Poast	21.46	3.33	28,498	21,378	21,081
Purslane + nettle	Alternative 5	Hand weed	300.00	10	643,890	896,460	884,010
Purslane + pigweed	Alternative 6	Balan DF	39.83	10	85,494	119,030	117,377
Purslane + pigweed +barnyardgrass	Alternative 7	Hand weed	300.00	20	1,287,780	1,792,920	1,768,020
			Total	100%	3,819,910	5,318,294	5,244,434
			Cost of Prefar		924,420	1,287,030	1,269,155
			Difference in cost from change		2,895,490	4,031,264	3,975,278

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

Table 25. Weed susceptibility chart for lettuce herbicides. Kerb is included for comparison as it can no longer be used in leaf lettuce. Note: C=control, P=partial control, N=no control. See full chart at UCIPM: http://www.ipm.ucdavis.edu/PMG/r441700311.html?printpage

Weeds	Balan	Prefar	Metam sodium	Kerb	Select Max /Poast
Barnyardgrass	C	C	C	P	C
Bluegrass, annual	C	C	C	C	Cleth. = C Seth. = N
Canarygrass	P	C	C	C	C
Chickweed	C	P	C	C	N
Goosefoot	C	C	C	C	N
Groundsel	N	N	C	N	N
Lambs quarters	C	C	C	C	N
Mallow	N	N	P	P	N
Nettle, burning	P	C	C	C	N
Nightshade, hairy	N	N	P	C	N
Pigweed	C	C	C	P	N
Purslane	C	C	C	C	N
Shepherds-purse	N	N	C	C	N
Sowthistle	N	N	C	N	N

Walnuts

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California produces over 95% of the walnuts in the United States and over 95% of California's walnuts are grown in the San Joaquin and Sacramento valleys. The remaining 5% are produced in the coastal region. Walnuts are produced on over 216,000 bearing acres with a gross value of over $553,600,000 (National Agricultural Statistics Service USDA 2006). The San Joaquin and Sacramento valleys are hot, dry interior valleys of the state while the coastal region is cool with higher humidity. Climate differences influence pest problems and crop management options. The San Joaquin and Sacramento valleys have severe insect problems, which include navel orangeworm (NOW), *Amyelois transitella*, spider mites (twospotted spider mite, *Tetranychus urticae* and Pacific spider mite, *Tetranychus pacificus*) and aphids (walnut aphid *Chromaphis juglandicola* and dusky-veined aphid, *Callaphis juglandis*) while both regions can have severe problems with walnut husk fly (WHF), *Rhagoletis completa* and codling moth (CM), *Cydia pomonella,* problems. Control of these pests requires the application of one or more insecticides or miticides per season.

In addition to the problems caused by insects, weeds cause a multitude of problems in walnut orchards by reducing the growth of young trees as they compete for water and nutrients. Weeds can also contribute to vertebrate and invertebrate pest problems as well as crown diseases. There are a variety of chemical and cultural control practices that can be employed against weeds (Cheetham 2007, Shrestha and Hembre 2006, Lanini and Roncoroni 1999). A common practice is to have a non-cultivated herbicide treated strip down the tree row with the orchard centers mowed to keep weeds short and managed. A tree row free of vegetation provides a pest free environment and increases harvest efficiency (Shrestha et al. 2008, Vargas et al. 2005). Orchard floor management is of particular importance to a walnut grower because the crop is harvested off the soil surface after being knocked from the trees and swept into windrows. Whether an orchard is tilled, non-tilled, herbicide-treated, or cover-cropped, a primary consideration when performing any cultural operation during the year must be to ensure that the orchard floor is in the best possible condition for harvesting and free of excessive vegetation. Most orchards are not tilled and require the use of herbicides and/or mowing to control weeds. Pre- and post-emergent herbicides are commonly used only in tree rows thus reducing the total amount of herbicides used on a per acre basis by 33%.

California Department of Pesticide Regulation (DPR) has identified a number of pesticides used on walnuts as contributing volatile organic compounds (VOC) to air quality problems in California. DPR is proposing to regulate pesticides with emission potentials (EP) of greater than 20%. Walnuts are the sixth largest VOC contributor of all agricultural commodities. Walnuts contributed over 150,000 lbs of VOC producing materials from emulsifiable concentrate formulations in 2005. Discussed here are all active ingredients with a 20% or greater EP that contribute about 1% or more of the total VOC produced on walnuts, which include chlorpyrifos, oxyfluorfen, pendimethalin and abamectin. These VOC producing pesticides and non-VOC producing alternative pesticides or formulations are discussed with regard to pest control activity and IPM potential.

Insecticides and Miticides

Chlorpyrifos – Lorsban 4E, with an EP value of 39, is widely used in walnuts for control of CM and WHF. Lorsban 4E also provides incidental control or suppression of NOW and walnut and dusky-veined aphids (Tables 1 and 2). Chlorpyrifos was applied at 222,448, 208,870 and 195,102 lbs of active ingredient (ai) to 121,883, 117,543 and 108,538 acres of walnuts from 2005 to 2007, respectively (California Department of Pesticide Regulation, 2005, 2006 and 2007). Since there is about 1/4 million acres of walnuts produced in the state, about half to a third of all walnut acreage is treated with Lorsban 4E and on average 1.8 lb ai/acre of chlorpyrifos or 3.6 pt of Lorsban 4E/acre was applied per application. Chlorpyrifos formulated as Lorsban 4E accounts for over 40% of the total emission on walnuts (Table 3). The percent of total emissions attributed to chlorpyrifos has declined from 41.4 % in 2005 to 39.5% in 2007 with a corresponding decrease in the amount of VOC emissions. In addition to the emulsifiable concentration formulation, a low VOC producing chlorpyrifos in a water emulsion formulation (Lorsban Advanced 3.76WE) was recently registered with an EP value of 18 and in a water dispersible granule formulation (Lorsban 75WG) with EP value of 4. Although Lorsban 75WG is registered on walnuts, it is not widely used on walnuts because of price and availability. Comparison studies on the seasonal efficacy between Lorsban 4E and Lorsban 75WG formulations showed that there was no significant difference in efficacy between these formulations for control of CM and NOW (Van Steenwyk et al. 1999). Comparative evaluations of Lorsban 4E and Lorsban 75WG for control of WHF and walnut and dusky-veined aphids have not been conducted. Lorsban 4E combined with a feeding stimulant bait such as NuLure is used for WHF. Control of WHF relies on feeding and direct contact with the spray and thus Lorsban 75WG should have similar efficacy to Lorsban 4E. Also, there should be no significant difference among the formulations for control of walnut aphids. In other crops where aphids cause a leaf distortion or cupping, e.g., cotton, Lorsban 4E has been more efficacious than other Lorsban formulations in aphid suppression (per. comm., L. Godfrey). It is speculated that Lorsban 4E has greater fumigation abilities and can penetrate the leaf distortion resulting in greater aphid mortality. However, neither walnut nor dusky-veined aphids cause leaf distortion or cupping and thus Lorsban 75WG should be as efficacious as the 4E formulation. Future research should compare the various formulations of chlorpyrifos for aphid control. Thus Lorsban 75WG could be a direct substitute for all uses of Lorsban 4E. Since Lorsban 4E was used at a rate of 3.6 pt/ac in 2006, then 2.36 lb of Lorsban 75WG would be an equivalent amount. Lorsban Advanced is formulated as a 3.76 EW product by Dow AgroSciences to reduce the VOC production found in Lorsban 4E. In preliminary studies in walnuts, Lorsban Advanced provided similar CM control compared to Lorsban 4E (Van Steenwyk data on file). Thus Lorsban Advanced will also be a direct replacement for Lorsban 4E. Since Lorsban 4E was used at a rate of 3.6 pt/ac, then 3.8 pt/ac of Lorsban Advanced would be an equivalent amount. The amount replacement with Lorsban 75WDG or Lorsban Advanced for Lorsban 4E will depend on the price and availability of the two chlorpyrifos products. In time, Lorsban Advanced will replace most uses of Lorsban 4E.

There are a number of low EP alternative insecticides for control of CM, NOW, WHF and walnut and dusky-veined aphids (Table 4). For CM and NOW, Lorsban 4E alternatives are: methoxyfenozide (Intrepid 2F) with an EP of 4.8, diflubenzuron (Dimilin 2L) with an EP of 6.6, phosmet (Imidan 70W) with an EP of 1.9, methyl parathion (Penncap-M) with an EP of 6.9, bifenthrin (Brigade 10WP) with an EP of 1.9 and esfenvalerate (Asana XL) with an EP of 11.1. For control of WHF, Lorsban alternatives are Imidan 70W, Asana XL and spinosad (Success 2SC) with an EP of 4.8 combined with bait such as NuLure while spinosad plus proprietary bait (GF-120) with an EP of 4.8 is a stand alone alternative. For walnut and dusky-veined aphids low EP alternatives to Lorsban 4E are imidacloprid (Provado 1.6F) with an EP of 2.3 and Imidan 70W. These insecticides have various advantages and disadvantages compared to Lorsban 4E. Lorsban 4E has an acute mammalian toxicity of about 200 mg/kg with the sign word of Warning while the sign word of Intrepid 2F, Dimilin 2L, Success 2SC and GF-120 is Caution; the sign word for Imidan 70W, Penncap-M, Brigade 10WP, Asana XL is Warning. Thus applicator's personal protection equipment (PPE) for the alternatives varies according to the toxicity. The applicator PPE for Lorsban 4E requires coveralls over short-sleeve shirt and short pants, chemical-resistant gloves, footwear plus socks, and headgear for overhead exposure and a NIOSH-approved dust mist filtering respirator prefix TC-21C. Applicator PPE requirements for Intrepid 2F, Dimilin 2L, Success 2SC and GF-120 are less stringent than Lorsban 4E while PPE requirements for Imidan 70W, Penncap-M, Brigade 10WP and Asana XL are similar to Lorsban 4E. Thus Intrepid 2F, Dimilin 2L, Success 2SC and GF-120 would require less PPE than Lorsban 4E and be a desirable change to the growers in respect to applicator safety while Imidan 70W, Penncap-M, Brigade 10WP, Asana XL would not require a significant change in PPE.

Lorsban 4E is typically used for first generation CM suppression of a season long management program. Lorsban 4E applied early in the season not only controls CM but also suppresses walnut and dusty-veined aphids. A number of alternatives to Lorsban 4E have been investigated. Imidan 50WP provided only about 25% control of CM in the untreated check in a study by Fouche and Van Steenwyk (1993) and about 50% of the control in a study by Van Steenwyk and Fouche (1994). A season long Brigade 10WP program (4 applications) provided lower CM and NOW infestation compared to an alternating program of Brigade 10WP and Lorsban 4E (Van Steenwyk and Nomoto 1997). In a study where a single application of Lorsban 75WG was applied for second generation CM control and compared to Penncap-M, Asana XL and Intrepid 80W, only Penncap-M achieved lower CM infestation, Asana XL allowed similar infestation and Intrepid 80W resulted in high infestation compared to the Lorsban 75WG (Van Steenwyk et al. 2000). First generation applications of Penncap-M had similar numbers of CM infested dropped nuts to Lorsban 4E in a study by Van Steenwyk et al. (2005a). Direct substitution for Lorsban 4E for CM control could be Lorsban Advanced at 3.8 pt/ac, Lorsban 75WG at 2.4 lb/ac, Penncap-M at 6.5 pt/ac, Brigade 10WP at 1 lb/ac, Asana XL at 12 oz/ac, Imidan 70W at 7.0 lb/ac with pH adjusted to less than 5.5 and Intrepid 2F at 24 oz/ac. Asana XL should not be applied in southern San Joaquin Valley because of spider mite flare-ups after its use. Intrepid 2F should be used against moderate CM populations. Dimilin 2L at 13.2 oz/ac would be a direct substitution for Lorsban 4E against low CM populations and combined with any of the other alternatives against a high CM population

Lorsban 4E provides both indirect and direct control of NOW. The indirect control comes from the suppression of CM. CM infested walnuts provide entry sites for NOW larvae during the season. This allows for a population increase of NOW before husk split. NOW cannot penetrate the walnut husk until husk split in the fall. After husk split NOW can directly infest the nuts. Growers with significant NOW infestation at husk split will treat the walnuts with a number of insecticides including Lorsban 4E. Brigade 10WP and Asana XL are all more effective in control of NOW than Lorsban 4E and all have a low EP value (Van Steenwyk et al. 1986 and 1987). In addition, Brigade 10WP has miticide effects and could possibly be used in the San Joaquin Valley without spider mite population explosions while both Asana XL and Brigade 10WP could be used in the Sacramento Valley which has much less spider mite pressure compared to the San Joaquin Valley. Lorsban 4E application for direct control of NOW could be replaced by Brigade 10WP at 1 lb/ac or Asana XL at 18 oz/ac. However, Asana XL has a 21-day PHI, which restricts their utility. Intrepid 2F provides excellent control of NOW in almonds and it should provide excellent NOW control in walnuts. Future research should compare the various formulations of chlorpyrifos, Intrepid 2F and other insecticides in a husk split application for NOW control.

Lorsban 4E combined with NuLure bait provides excellent control of WHF. Lorsban 4E is often used for simultaneous control of both CM and WHF when treatment timing coincides. The substitution of Success 2SC combined with NuLure bait for Lorsban 4E also provided excellent control of WHF but not CM (Van Steenwyk et al. 2003). Asana XL or Imidan 70W combined with NuLure bait will also provide excellent control of WHF and CM and would be direct substitutions for Lorsban 4E. In addition, excellent control of low to moderate WHF populations can be achieved with multiple applications of GF-120 (Van Steenwyk et al. 2005a). Thus, Lorsban 4E at 4 pt/ac plus NuLure bait could be replaced with Success 2SC at 3.2 oz/ac, Imidan 70W at 7.0 lb/ac or Asana XL at 12 oz/ac plus Nulure bait or 4 to 8 applications of GF-120 at 20 oz/ac (Van Steenwyk et al. 2006). Malathion 8EC at 3 pt/ac combined with NuLure bait is the grower standard. However, Malathion 8EC has an EP value of 39.15 and is not considered a viable Lorsban 4E replacement.

Lorsban 4E also provides control of walnut and dusty-veined aphids. Provado 1.6F provided excellent control of pecan aphids (Dutcher 2005). In walnut aphid trials conducted in San Joaquin County, Provado 1.6 F provided excellent control of walnut aphids (per. comm., J. A. Grant data on file). Also, Imidan 70W at 7 lb/ac has provided acceptable control. Thus, Lorsban 4EC alternatives for walnut aphid control are Provado 1.6F at 4 oz/ac, Lorsban 3.76EW at 3.8 pt/ac, Lorsban 75WG at 2.4 lb/ac and Imidan 70W at 7 lb/ac.

The cost of the low-VOC alternatives are variable, ranging from about $28.96/ac for Asana XL to Imidan 70W at $102.73 (Table 5). The most cost effective alternative for CM control would be Lorsban Advanced, Penncap-M and Asana XL, with Lorsban 75WG, Imidan 70W and Intrepid 2F being more expensive alternatives. However, only Lorsban Advanced, Penncap-M, Lorsban 75WG and Brigade 10WP would be viable alternatives when spider mites and aphid management is considered. The most cost effective alternative for aphid control would be Lorsban Advanced and Provado 1.6F with a price similar to Lorsban 4E and the most cost effective alternative for WHF control would be Lorsban Advanced, Success 2SC, GF-120 and Asana XL. There are large numbers of available alternatives to Lorsban 4E for growers to select. However, based on the projected replacement of alternative insecticides, walnut growers will have increased insecticide costs (Table 6). It is estimated that the cost of alternatives would be about $443,512 to $498,643 more than the current cost or an increase of about 9% with the elimination of Lorsban 4E.

Abamectin – Agri-Mek 0.15EC and Abba 0.15EC, with an EP value of 55.1, is the second most widely used miticide on walnuts. Only Omite 30W is applied to more acres than Agri-Mek 0.15EC. In 2005, over 190 lb of active ingredient of abamectin was applied to more than 13,900 acres of walnuts in over 420 applications (California Department of Pesticide, 2005). In 2007, over 470 lb of active ingredient of abamectin was applied to more than 31,778 acres of walnuts in over 922 applications (California Department of Pesticide Regulation, 2007). This increase in use was a response to greater mite pressure, increased resistance to propargite and a reduced cost due to the loss of patent. Abamectin is now a generic insecticide and is produced by MANA. Abamectin, formulated as Agri-Mek 0.15EC, accounts for over 0.8% of the total emission on walnuts in 2005 (Table 3). The percent of total emissions attributed to abamectin has increased to about 1.8% in 2007 (Table 3). Currently research is underway to develop a new formulation (soluble concentrate) of abamectin that will be below the 20% EP value. However, this new formulation is not currently available. It is hoped that the new formulation will be registered for use in California next year. Agri-Mek 0.15EC is locally systemic and needs to be applied early in the season (May) when foliage is still developing. Also, Agri-Mek 0.15EC needs to be combined with a low rate (1/4 to 1%) of horticultural oil, which aids the movement of Agri-Mek 0.15EC into the leaf tissue. Agri-Mek 0.15EC is used as a prophylactic treatment and is applied where webspinning mites are a perennial problem. Agri-Mek 0.15EC is effective against Omite 30W resistant webspinning mite populations.

There are a number of low EP alternative miticides for control of webspinning mites (Table 13). These alternatives include: propargite (Omite 30W) with an EP of 1.84, dicofol (Kelthane MF) with an EP of 3.2, bifenazate (Acramite 50W) with an EP of 1.85, fenbutatin-oxide (Vendex 50WP) with an EP of 1.85, clofentezine (Apollo SC) with an EP of 5.7, hexythiazox (Savey 50DF) with an EP of 1.02 and spirodiclofen (Envidor 2SC) with an unknown EP value. Omite 30W is the most widely used miticide in walnuts. Omite 30W will control all motile stages of webspinning mites and should be applied at 7 lb/ac. Resistance of webspinning mites to Omite 30W has been reported in the southern San Joaquin Valley and only one application of Omite 30W should be applied per season. Thus the usage of Omite 30 would increase with the elimination of Agri-Mek 0.15EC but only marginally because of resistance. Kelthane MF is an older miticide and resistance has developed to Kelthane MF. Kelthane MF is effective against all motile forms and can be effectively used to control webspinning mites but applications should be applied only once every other year. Repeated uses of Kelthane in the same year may result in a lack of efficacy. Kelthane MF should be applied at 64 oz/ac. Thus the usage of Kelthane MF would increase with the elimination of Agri-Mek 0.15EC but only marginally because of resistance. Acramite 50W is a relatively new miticide and is effective against all motile forms of webspinning mites. Acramite 50W should be applied at 14 oz/ac. The use of Acramite 50W would increase with the elimination of Agri-Mek 0.15EC. However, the higher cost of Acramite 50W compared to the other alternatives would limit the increase of Acramite 50W usage (Table 14). Apollo SC is effective against eggs and immature stages and can be used against Omite 30W resistant populations. Apollo SC should be applied at 4.8 oz/ac. The use of Apollo SC would increase with the elimination of Agri-Mek 0.15EC because of the lower cost of Apollo SC compared to Savey 50DF, Vendex 50WP or Envidor. Apollo SC must be applied at the first signs of mite infestation to prevent damage and would be used in the same manner as Agri-Mek 0.15EC. Savey 50DF is a mite growth regulator and is effective against eggs and immature stages. In addition, exposed adult females produce sterile eggs. Savey 50DF should be applied at 4.8 oz/ac. The high cost of Savey 50DF as compared to other alternatives would limit its use. Vendex 50WP is another ovicide and should be applied at 1.7 lb/ac and Envidor 2SC is a newly registered miticide and should be applied at 18 oz/ac. Apollo SC, Savey 50DF, Vendex 50WP or Envidor should be applied at the first signs of mite infestation to prevent damaging populations from developing and excellent coverage is required for effective control. Effective mite management should alternate ovicidal and adulticidal miticides materials between years and not repeat the same mode of action every year. In addition to the conventional miticides, Brigade 10WP at 1 lb/ac used for control of CM and NOW has resulted in significantly lower numbers of webspinning mites and European red mite compared to the grower standard of Lorsban 4E and Azinphos-M 50W (Van Steenwyk and Nomoto 1997).

Although the cost of Agri-Mek 0.15EC has decreased with the loss of patent.,the large number of available alternatives to Agri-Mek 0.15EC at similar or lower prices would allow for a minimal economic impact to walnut growers with the cancellation of Agri-Mek 0.15 EC registration (Table 15). The cost of alternatives ranges from $37.60 per acre for Dicofol to $121.52 for hexythiazox. Based on the projected replacement miticides cost, walnut growers would see about a 35% decrease in cost. However, the elimination of Agri-Mek 0.15EC would eliminate an alternative mode of action which will result in the potential of increase miticide resistance in the future.

Herbicides

Pendimethalin – Pendimethalin, formulated as Prowl 3.3EC, has an EP potential of 42. Pendimethalin is applied pre-emergence by ground one time per season at the rate of 4 pt per acre. Prowl 3.3EC is labeled for non-bearing walnuts so its use is limited. It is effective on annual grasses and some broadleaf weeds. The number of treated acres with pendimethalin has increase dramatically from 6,569 acres in 2005 to 27,080 acres in 2007 (Table 2).
An alternative to Prowl 3.3 EC is Prowl H_2O (Table 7). Prowl H_2O has recently been registered in California for use in both bearing and non-bearing fruit and nut orchards. This has resulted in a dramatic increase in acres treated with pendimethalin from 2005 to 2007. The availability of Prowl H_2O has expanded the use of pendimethalin in walnuts. However, the expanded use of pendimethalin has not resulted in an increased in amount of total VOC emission produced since growers are using Prowl H_2O instead of Prowl 3.3 EC (Table 3). Prowl H_2O is a water-based formulation, and thus has a lower EP than Prowl 3.3 EC, which is a petroleum solvent-based formulation. The rate of Prowl H_2O has increased to 12 pts per season, which is higher than the Prowl 3.3EC and should provide very good long-term weed control. Another broad spectrum alternative to Prowl 3.3EC is simazine, which has an EP of 1 when formulated as a wettable powder (Princep Caliber 90) or an EP value of 9 when formulated as a liquid (Princep 4L). Simazine controls many of the weeds controlled by pendimethalin, but does not control several important grasses which are controlled by pendimethalin, including junglerice, *Echinochloa colona*, large crabgrass, *Digitaria sanguinalis* and sandbur, *Cenchrus spp*. Also, simazine is considered to be a ground water contaminant and requires a use permit within Ground Water Protection Areas. The Ground Water Protection Area permit makes simazine a less attractive VOC alternative product in certain areas. Oryzalin (Surflan DF 85%) is a similar dinitroanaline herbicide as pendimethalin. Surflan DF 85% controls the same weeds and has application timing similar to Prowl 3.3EC. Surflan DF 85% has no ground water or VOC issues. Availability of Surflan DF 85% has occasionally been a problem, which has caused price instability. Both simazine and oryzalin would be viable alternatives to Prowl 3.3EC if Prowl 3.3EC registration is lost (Tables 7 and 8). The replacement cost for Prowl 3.3EC has decreased substantially from 2005 to 2007 with the decreased use of Prowl 3.3 EC (Table 9). Replacement cost from 2005 was $110,028 and decreased to $33,203 in 2007. Alternatives to Prowl 3.3EC could increase cost by about 53%.

Oxyfluorfen – Goal 2XL, with an EP value of 39, is a nonselective pre- and post-emergent broadleaf herbicide. The use of oxyfluorfen has been very stable from 2005 to 2007 with about 112,000 treated acres or about half to a third of the total walnut acres (Table 2). Oxyfluorfen formulated as Goal 2XL accounts for between 13 to 19% of the total emission on walnuts (Table 3). Goal 2XL is commonly applied as a post-emergent herbicide following harvest up to February 15. Higher rates are needed for long-term residual control. It is often combined with glyphosate to increase efficacy on various broadleaf weeds and grass species. Oxyfluorfen is commonly used because it is an effective pre- and post-emergent on many difficult to control weeds such as malva, *Malva* spp., burning nettle, *Urtica urens*, purslane, *Portulaca oleracea* and fillaree, *Erodium* spp. The herbicide is generally applied one time in the fall or winter months for annual weed control in orchard tree rows. The loss of Goal 2XL would create a gap in weed control and be of great economic concern to the industry. Fortunately, a new formulation of oxyfluorfen (GoalTender®) with an EP value of 5 has recently been registered as an alternative to the Goal 2XL. Substituting GoalTender for Goal 2XL would eliminate the VOC issues and provide equivalent weed control. The new formulation of GoalTender herbicide provided comparable control to most of the same weeds as Goal 2XL as shown in experiments conducted in California (data on file).

Flumioxazin trade name Chateau® and rimsulfuron Matrix® are two newly registered dry formulation herbicides with unknown EP values. Flumioxazin is a PPO inhibitor with chemistry similar to oxyfluorfen. Rimsulfuron is a sulfonylurea herbicide registered for general control of winter and summer annuals. Combined with glyphosate (Roundup Original Max), Chateau and Matrix provide control of many of the same weed species as Goal XL and pendimethalin and contain post- and pre-emergent activity using the same application methods and timing as oxyfluorfen. These herbicides are especially important to control increasing weed populations of horseweed *Conyza canadensis*, fleabane *Conyza bonariensis*, and willowherb *Epilobium brachycarpum*.

Glufosinate (Rely 200®) with an EP value of 15, paraquat (Gramoxone-Inteon®) with an EP value of 7 or less, and glyphosate (Roundup Original Max) with an EP value of 4.8 are contact post-emergent herbicides that are used in tank mix combinations to complement or substitute for Goal 2XL post activity. They control many of the same weed species as oxyfluorfen. Unlike oxyfluorfen, Rely 200, Gramoxone Inteon and glyphosate have no soil residual properties. They would only be an option to substitute for the post-emergent portion of oxyfluorfen. Also, paraquat is a restricted use category I herbicide that requires specialized handling and requires the applicator to wear a respirator. These issues may limit the use of paraquat applications. GoalTender or a combination of GoalTender and Rely, Roundup® or Gramoxone Inteon 2E combined with GoalTender, Matrix or Chateau would replace Goal 2XL with equivalent control (Tables 10 and 11). However, there would be an increase in herbicide costs of about 32% with the elimination of Goal 2XL (Table 12).

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Tables

Table 1. VOC Producing Pesticides and Alternatives

	Materials	Yield loss (%)	Quality change
VOC Producing Pesticide	**Lorsban 4E**	0	
Alternative 1	Lorsban Advanced		None
Alternative 2	Lorsban 75 WG		None
Alternative 3	Penncap-M		None
Alternative 4	Imidan 70W		None
Alternative 5	Intrepid 2F		None
Alternative 6	Brigade 10WP		None
Alternative 7	Asana XL		None
Alternative 8	Provado 1.6F		None
Alternative 9	Success 2SC		None
Alternative 10	GF-120		None
Alternative 11	Dimilin 2L		None
VOC Producing Pesticide	**Prowl 3.3EC**	0	
Alternative 1	Prowl H_2O		None
Alternative 2	Surflan Flowable		None
Alternative 3	Princep 4L and Caliber 90		None
VOC Producing Pesticide	**Goal 2XL**	0	
Alternative 1	Goal Tender		None
Alternative 2	Rely 200		None
Alternative 3	Gramoxone Inteon		None
Alternative 4	Matrix		None
Alternative 5	Chateau		None
VOC Producing Pesticide	**Agri-Mek 0.15EC**	0	
Alternative 1	Kelthane MF		None
Alternative 2	Omite 30W		None
Alternative 3	Acramite 50WS		None
Alternative 4	Apollo SC		None
Alternative 5	Savey 50DF		None
Alternative 6	Vendex 50WP		None
Alternative 7	Envidor 2SC		None

Table 2. VOC Producing Pesticides - Application Details

Chemical name	Trade name	Pest(s) controlled	No. acres treated[a] 2005	2006	2007	Months of appls.	Rate form ac/ appl[b]	% control
Chlorpyrifos	Lorsban 4E	Codling moth, walnut husk fly, walnut aphids	121,543	117,205	108,105	Apr. – Aug.	3.6 pt/ac	90
Pendimethalin	Prowl 3.3EC	Grasses & broadleaf weeds	4,440	2,903	1,340	Nov. – Feb. Non bearing	64 oz/ac	> 80%
Oxyfluorfen	Goal 2XL	Broadleaf weeds	112,963	114,771	110,479	Dec. – Feb.	19 oz/ac	> 80%
Abamectin	Agri-Mek 0.15EC	Web spinning mites	13,961	23,816	29,984	May – Jun.	11 oz/ac	80

[a] Use rates from 2005 to 2007 pesticide use report data.
[b] Formulated amount based on 2005 pesticide use report data i.e. active ingredient/ac modified to formulated amount/ac.

Table 3. Amount (lbs) and percent of total VOC emission produced by active ingredients for 2005 through 2007 in walnuts

		2005		2006		2007	
Chemical name	Trade name	Amount[a]	Percent	Amount[a]	Percent	Amount[a]	Percent
Chlorpyrifos	Lorsban 4E	262.1	41.4	243.3	40.3	226.1	39.5
Pendimethalin	Prowl 3.3EC	7.3	1.2	4.4	0.7	4.0	0.7
Oxyfluorfen	Goal 2XL	83.7	13.2	93.6	15.5	106.8	18.7
Abamectin	Agri-Mek 0.15EC	5.3	0.8	7.9	1.3	10.1	1.8

[a] Amount times 1000 pounds from 2005 to 2007 pesticide use report data and Dept of Pesticide Regulation.

Table 4. Alternative insecticides to Lorsban 4E - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl.[a]	Appl. method	Percent control[b]
Chlorpyrifos	Lorsban Advanced	CM, WHF & aphids	1	Apr. – Aug.	3.8 pt/ac	Ground	100
Chlorpyrifos	Lorsban 75 WG	CM, WHF & aphids	1	Apr. – Aug.	2.4 lb/ac	Ground	100
Methyl parathion	Penncap-M	CM, WHF	1	Apr. – Aug.	6.5 pt/ac	Ground	100
Phosmet	Imidan 70W	CM, WHF & aphids	1	Apr. – Aug	7.0 lb/ac	Ground	100
Methoxyfenozide	Intrepid 2F	CM	2	Apr. – Aug.	24.0 oz/ac	Ground	100
Bifenthrin	Brigade 10WP	CM & mites	1	Apr. – Aug.	1.0 lb/ac	Ground	100
Esfenvalerate	Asana XL	CM & WHF	1	Apr. – Aug.	12.0 oz/ac	Ground	100
Imidacloprid	Provado 1.6F	Aphids	1	Apr. – Aug.	4.0 oz/ac	Ground	100
Spinosad	Success 2SC	WHF	1	Apr. – Aug.	3.2 oz/ac	Ground	100
Spinosad	GF-120	WHF	4	Apr. – Aug.	20.0 oz/ac	Ground	100
Diflubenzuron	Dimilin 2L[c]	CM	1	Apr. – Aug.	13.2 oz/ac	Ground	100

[a] Most use rates based on 2006 PUR data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Lorsban 4E.
[c] Dimilin will be combined with Alternatives 1 to 7 for very high CM populations.

Table 5. Cost of Lorsban 4E and replacement cost of alternative insecticides for Lorsban 4E

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl. method	Total material cost/ac	Total material & appl. cost/ac [a]
Chlorpyrifos	Lorsban 4E	6.40	pt	3.6	Ground	23.04	39.04
Chlorpyrifos	Lorsban Advanced	8.74	pt	3.8	Ground	25.27	41.27
Chlorpyrifos	Lorsban 75 WG	20.10	lb	2.4	Ground	48.24	64.24
Methyl parathion	Penncap-M	5.17	pt	6.5	Ground	33.61	49.61
Phosmet	Imidan 70W	12.39	lb	7.0	Ground	86.73	102.73
Methoxyfenozide	Intrepid 2F	2.96	fl oz	24.0	Ground	71.04	87.04
Bifenthrin	Brigade 10WP	47.15	lb	1.0	Ground	47.15	63.15
Esfenvalerate	Asana XL	1.08	fl oz	12.0	Ground	12.96	28.96
Imidacloprid	Provado 1.6F	5.47	fl oz	4.0	Ground	21.88	37.88
Spinosad	Success 2SC	7.00	fl oz	3.2	Ground	22.40	38.40
Spinosad	GF-120	1.00	fl oz	20.0	Ground	20.00	36.00
Diflubenzuron	Dimilin 2L	1.92	fl oz	13.2	Ground	25.34	41.34

[a] Application cost of ground speed sprayer is $16.00/ac.

Table 6. Replacement cost of alternative scenarios for Lorsban 4E

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Lorsban 4E replacement acreage	Replacement cost[a] 2005	2006	2007
CM, WHF and aphids	Alternative 1	Lorsban Advanced	41.27	86	4,263,680	4,111,477	3,792,287
CM, WHF and aphids	Alternative 2	Lorsban 75WG	64.24	5	390,397	376,461	347,235
CM and WHF	Alternative 3	Penncap-M	49.61	1	60,292	58,139	53,626
CM, WHF and aphids	Alternative 4	Imidan 70W	102.73	1	124,861	120,404	111,057
CM	Alternative 5	Intrepid 2F	87.04	1	105,791	102,015	94,095
CM and mites	Alternative 6	Brigade 10WP	63.15	1	76,755	74.015	68,269
CM and WHF	Alternative 7	Asana XL	28.96	1	35,199	33,942	31,307
Aphids	Alternative 8	Provado 1.6F	37.88	1	46,041	44,397	40,950
WHF	Alternative 9	Success 2SC	38.40	1	46,673	45,007	41,513
WHF	Alternative 10	GF-120	36.00	1	43,756	42,194	38,918
CM	Alternative 11	Dimilin 2L	41.34	1	50,251	48,457	44,695
				100%	5,243,695	5,056,507	4,663,950
			Difference in cost from change[b]		(498,643)	(480,842)	(443,512)

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs.

Table 7. Alternative herbicides to Prowl 3.3EC - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl [a]	Appl method	% control [b]
Pendimethalin	Prowl H_2O	Broadleaf weeds & grasses	1 – 2	Nov. – Mar.	64-201 oz/ac	Ground/ Chemigation	> 99%
Oryzalin	Surflan DF 85%	Broadleaf weeds & grasses	1.5	Min Time between Appl = 2.5 mo.	1.9 lb/ac	Ground	>75%
Simazine	Princep Caliber 90	Broadleaf weeds & grasses	1	Oct. – Mar. WAP[c]	1.60 lb/ac	Ground	>70%

[a] Most use rates based on 2005 pesticide use report data, i.e., active ingredient/ac modified to formulated amount/ac.
[b] Compared to Prowl 3.3EC.
[c] Restrictions in water protection areas.

Table 8. Cost of Prowl 3.3EC and replacement cost of alternative herbicides to Prowl 3.3EC

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl method	Total material cost/ac	Total material & appl. cost/ac [a]
Pendimethalin	Prowl 3.3EC	39.62	Gal	0.18	Ground	7.20	16.20
Pendimethalin	Prowl H_2O	33.00	Gal	0.26	Ground	8.60	24.60
Oryzalin	Surflan DF 85%	24.69	Lb	1.06	Ground	26.14	39.64
Simazine	Princep Caliber 90	5.34	Lb	0.51	Ground	2.75	11.37

[a] Total material cost per treated acre plus application cost of $9.00 per acre times number of applications.

Table 9. Replacement cost of alternative scenarios for Prowl 3.3EC

Target Pest(s)	Alternatives	Trade name	Cost per acre	Percent of Prowl 3.3EC replacement acreage	Replacement cost[a] 2005	2006	2007
Foxtail, Watergrass, annual grasses and broadleave weeds	Alternative 1	Prowl H_2O	24.60	80	87,377	57,139	26,368
Foxtail, Watergrass, annual grasses and broadleave weeds	Alternative 2	Surflan DF 85%	55.91	10	17,601	11,510	5,311
Foxtail, Watergrass, annual grasses and broadleave weeds	Alternative 3	Princep Caliber 90	17.54	10	5,050	3,302	1,524
				100%	110,028	71,951	33,203
			Difference in cost from change[b]		(38,085)	(24,905)	(11,493)

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs.

Table 10. Alternative herbicides to Goal 2XL - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl [a]	Appl method	Percent control [b]
Oxyfluorfen	GoalTender	Broadleaf weeds	1	Oct. – Feb. 15	16 to 64 oz/ac	Ground/ chemigation	> 99%
Glufosinate	Rely 200	Broadleaf weeds & grasses	2	Year around	58 to 115 oz/ac	Ground	>80%
Paraquat	Gramoxone Inteon 2E	Broadleaf weeds & grasses	2	Year around	43 oz/ac	Ground	>80%
Glyphosate	Roundup original max	Broadleaf weeds & grasses (post)	2	Year around	16 oz/ac	Ground	>80%
Rimsulfuron	Matrix 25DF	Broadleaf weeds & grasses	1	Nov. – March	4.0 oz/ac	Ground	> 90%
Flumioxazin	Chateau 51% WDG	Broadleaf weeds & grasses	1	Nov. – March	12.0 oz/ac	Ground	> 90%

[a] Most use rates based on 2005 pesticide use report data, i.e. active ingredient/ac modified to formulated amount/ac.
[b] Compared to Goal 2XL.

Table 11. Cost of Goal 2XL and replacement costs of alternative herbicides to Goal 2XL

Chemical name	Trade name	Cost	Unit	Rate/ac	Appl method [a]	Total material cost/ac	Total material & appl. cost/ac [a]
Oxyfluorfen	Goal 2XL	105.00	gal	0.25	Ground	5.25	14.25
Oxyfluorfen	GoalTender	210.00	gal	0.125	Ground	5.25	14.25
Glufosinate	Rely 200	63.00	gal	0.45	Ground	11.32	29.32
Glyphosate	Roundup Original Max	68.70	gal	0.34	Ground	2.75	11.75
Paraquat	Gramozone Inteon 2E	43.92	gal	0.25	Ground	6.59	24.59

[a] Application cost of ground speed sprayer is $9.00/ac.

Table 12. Replacement cost of alternative scenarios for Goal 2XL

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Goal 2XL replacement acreage	Replacement cost[a] 2005	2006	2007
Broadleaf weeds and common groundsel	Alternative 1	Goal Tender	14.25	20	643,889	654,194	629,729
Broadleaf weeds and common groundsel	Alternative 2	Rely 200 tank mixed with GoalTender	25.57	10	866,450	880,317	847,395
Broadleaf weeds and common groundsel	Alternative 3	Gramoxone Inteon 2E tank mixed with GoalTender	20.84	10	235,392	239,160	230,216
Broadleaf weeds and common groundsel	Alternative 4	Roundup Original Max tank plus GoalTender	17.00	20	384,029	390,175	375,584
Broadleaf weeds, horseweed, fleabane, malva	Alternative 5	Roundup Original Max tank mix with Matrix	26.15	20	590,751	600,206	577,760
Broadleaf weeds and horseweed, fleabane, malva, annual weeds	Alternative 6	Roundup Original Max tank mix with Chateau	28.55	20	644,973	655,296	630,790
				100%	3,365,484	3,419,348	3,291,474
			Difference in cost from change[b]		(856,184)	(869,887)	(837,356)

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs.

Table 13. Alternative miticides to Agri-Mek 0.15EC - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl [a]	Appl method	% control [b]
Propargite	Omite 30W	Webspinning mites	1	Jun-Aug	7.0 lb/ac	Ground	100
Dicofol	Kelthane MF	Webspinning mites	1	Jun-Aug	64.0 oz/ac	Ground	100
Bifenazate	Acramite 50WP	Webspinning mites	1	Jun-Aug	13.7 oz/ac	Ground	100
Clofentezine	Apollo 1SC	Webspinning mites	1	Jun-Aug	4.8 oz/ac	Ground	100
Hexythiazox	Savey 50WP	Webspinning mites	1	Jun-Aug	5.1 oz/ac	Ground	100
Fenbutatin-oxide	Vendex 50WP	Webspinning mites	1	Jun-Aug	1.7 lb/ac	Ground	100
Spirodiclofen	Envidor 2SC	Webspinning mites	1	Jun-Aug	18.0 oz/ac	Ground	100

[a] Most use rates based on 2005 pesticide use report data, i.e., active ingredient/ac modified to formulated amount/ac.

[b] Compared to Agri-Mek 0.15EC.

Table 14. Cost of Agri-Mek 1.5EC and replacement costs of alternative miticides to Agri-Mek 0.15EC

Chemical name	Trade name	Cost	Unit	Ave. Rate/ac	Appl method [a]	Total material cost/ac	Total material & appl. cost/ac [a]
Abamectin	Agri-Mek 0.15EC	7.82	fl oz	11.00	Ground	86.02	102.02
Propargite	Omite 30W	8.23	lb	7.00	Ground	57.61	73.61
Dicofol	Kelthane MF	0.45	fl oz	48.00	Ground	21.60	37.60
Bifenazate	Acramite 50WP	5.38	oz	13.70	Ground	73.71	89.71
Clofentezine	Apollo SC	7.83	fl oz	4.80	Ground	37.58	53.58
Hexythiazox	Savey 50WP	20.69	oz	5.10	Ground	105.52	121.52
Fenbutatin-oxide	Vendex 50WP	34.59	lb	1.70	Ground	58.80	74.80
Spirodiclofen	Envidor 2SC	3.52	fl oz	18.00	Ground	63.36	79.36

[a] Application cost of ground speed sprayer is $16.00/ac.

Table 15. Replacement cost of alternative scenarios for Agri-Mek 0.15EC

Target pest(s)	Alternatives	Trade name	Cost per acre	Percent of Agri-Mek 1.5EC replacement acreage	Replacement cost[a] 2005	2006	2007
Webspinning mites	Alternative 1	Kelthane MF	37.60	5	26,247	44,774	56,370
Webspinning mites	Alternative 2	Omite 30W	73.61	50	513,841	876,549	1,103,569
Webspinning mites	Alternative 3	Acramite 50WP	89.71	25	313,100	534,110	672,441
Webspinning mites	Alternative 4	Apollo 2SC	53.58	5	37,405	63,808	80,334
Webspinning mites	Alternative 5	Savey 50WP	121.52	5	84,827	144,705	182,183
Webspinning mites	Alternative 6	Vendex 50WP	74.80	5	52,217	89,076	112,145
Webspinning mites	Alternative 7	Envidor 2SC	28.39	5	19.818	33,807	42,563
				100%	1,047,456	1,786,829	2,249,606
			Difference in cost from change[b]		376,864	642,882	809,384

[a] Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.
[b] Positive number is savings, negative number is increase in costs.

Proposed exemptions to San Joaquin Valley Ozone Nonattainment Area Use Restrictions

Robert Van Steenwyk, UC Berkeley and
Karen Klonsky, UC Davis

March, 2012

Growers, pest control advisors and manufactures were surveyed regarding pest management consequences of restricting high-emission formulations of abamectin, chlorpyrifos, gibberellins and oxyfluorfen. The survey focused on the San Joaquin Valley from 1 May through 31 October and addressed the efficacy of alternatives and effects on management practices.

Abamectin – Since the industry has not had the new, low-VOC abamectin products for a full season yet, growers and PCAs have relatively little experience with the new formulations. Limited use during the 2011 season did not find any significant differences with the new formulations. Field trial data also show that the low-emission products have equivalent efficacy (Van Steenwyk, unpublished). Aside from a slight increase in cost, restricting the high-emission formulations should not cause any problems, but additional experience with the 2012 growing season is needed to confirm this. Manufacturers would be wise to educate end-users on formulation changes so that they apply the appropriate amount during the first few years of use.

Chlorpyrifos – There was general consensus that the low-emission formulation of chlorpyrifos is as efficacious as the high-emission formulations for most pests. An exemption may be necessary for some pest species, e.g., cotton aphid, which are difficult to cover with insecticides because they are concealed within the foliage. There are data on file that show lower efficacy for controlling cotton aphid with the low-emission formulation. Control can be achieved by the low-emission formulation of chlorpyrifos and other low-emission insecticides if applied before the pest species become concealed within the foliage. After aphids are protected within the foliage, only neonicotinoids can provide acceptable control. However, neonicotinoid insecticides are used early in the growing season for white fly and aphid control. Resistance to the neonicotinoid insecticides has been detected in cotton aphid and reliance on additional neonicotinoid insecticide applications late in the season will exacerbate the problem. We advise exempting the high-emission formulations for cotton aphid on cotton post boll opening (September through October). Based on 2010 PUR data, the exemption would result in 29,085 acres being treated with the high-emission formulation of chlorpyrifos.

Gibberellins – There is general consensus that the low-emission formulations of gibberellins are as efficacious as the high-emission formulations. However, there is concern regarding the difficulty of measuring small amounts of powder in the field. For example, on certain cultivars (Ruby Seedless, Crimson Seedless and other fresh market grapes) as little as 0.5 to 1 g AI/ac are recommended for thinning. Using the high-emission formulation (4% liquid), 0.5 to 1 fl oz/ac would be required. This amount is easily measured in the field. Using the 40% powder (low-VOC) formulation, 0.097 to 0.19 oz/ac would be required, or using the 5% powder compliant formulation, 0.78 to 1.5 oz/ac would be required. It would be very difficult to measure accurately in the field using the 5% powder and practically impossible using the 40% powder.

However, 8 to 16 g AI/ac is recommended for sizing of Ruby Seedless and 4 to 8 g AI/ac for Crimson Seedless and others. These amounts are difficult to measure in the field but it is possible, particularly if the 5% powder is used. The consequence of an applying too little or too much gibberellin could be devastating to the grower since it could cause no thinning or complete fruit abortion and possibly reduce crop yields the following year. We recommend that applications of 5 - 8 g or less of high-emission formulations of gibberellin be exempt from regulations until manufacturers begin distributing powdered gibberellin products in small quantity, e.g., 1 g water dispersible bags. Based on 2010 PUR data and a 5 g/acre exemption, this would result in 55,213 acres being treated with the high-emission formulation of gibberellins.

*Oxyfluorfe*n – There is general consensus that the low-VOC formulation of oxyfluorfen is equally efficacious as a pre-emergence herbicide as compared to the high-emission formulation. However, it is also generally recognized that the low-emission formulation of oxyfluorfen is not as effective as a post-emergence herbicide. Mitigation of this problem would require the addition of a low dose of a low-emission post-emergence herbicide, i.e., paraquat, glyphosate, glufosinate, flumioxazin, carfentrazone, glyphosate, glufosinate. The combination of both the low-VOC formulation of oxyfluorfen and low-emission post-emergence herbicide would achieve the same efficacy but would increase the cost to growers.

The cost of the additional post-emergence herbicides ranges from $1.19/acre for glyphosate to $19.30/acre for saflufenacil (Table 1). For the 375,673 acres of the affected commodities, the additional cost of the low-emission post-emergence herbicide ranges from $446,000 for glyphosate to $7,250,000 for saflufenacil (Table 2).

Table 1. High-VOC oxyfluorfen (Goal 2XL) vs alternative materials. Includes $9/acre application costs. 100% of fields or orchards treated.

Active ingredient (trade name)		Lbs AI/ gallon	Cost/unit	Rate* unit/acre	Unit	Per acre/ application Materials $	Total/acre Mat +Appl $	Total $ Mat/ Treated Ac	Total/acre Mat +Appl $ Treated Area
oxyfluorfen (Goal 2XL)	**VOC**	**2**	**$69**	**0.281**	**lb AI**	**$19.41**	**$28.41**	**$19.41**	**$28.41**
oxyfluorfen (GoalTender)	Alt	4	$69	0.281	lb AI	$19.41	**$28.41**	**$19.41**	**$28.41**
glyphosate	Kicker	4	$5	0.250	lb AI	$1.19	**$1.19**	$1.19	**$1.19**
paraquat (Gramoxone Inteon)	Kicker	3	$16	0.625	lb AI	$10.21	**$10.21**	$10.21	**$10.21**
carfentrazone (Shark)	Kicker	1.9	$153	0.031	lb AI	$4.75	**$4.75**	$4.75	**$4.75**
glufosinate (Rely)	Kicker	2.34	$41	0.400	lb AI	$16.41	**$16.41**	$16.41	**$16.41**
pyraflufen-ethyl (Venue)	Kicker	0.17	$3,435	0.005	lb AI	$15.97	**$15.97**	$15.97	**$15.97**
saflufenacil (Treevix)	Kicker	0.7	$3,529	0.005	lb AI	$19.30	**$19.30**	$19.30	**$19.30**
esterified vegetable oil (Hasten)	Kicker	NA	$4	2.000	pint	$7.00	**$7.00**	$7.00	**$7.00**

*Broadcast Acre

Table 2. Increased cost for substituting GoalTender plus various kickers for Goal 2XL by crop*

Crop	# of Apps	Acres Treated	glyphosate	paraquat (Gramoxone Inteon)	carfentrazone (Shark)	glufosinate (Rely)	pyraflufen-ethyl (Venue)	saflufenacil (Treevix)	esterified vegetable oil (Hasten)
Almond	4,822	270,405	$321,106	$2,760,384	$1,283,854	$4,437,415	$4,318,030	$5,218,817	$1,892,835
Pistachio	754	51,481	$61,134	$525,535	$244,426	$844,816	$822,087	$993,583	$360,367
Walnut	1,053	28,343	$33,657	$289,335	$134,570	$465,116	$452,602	$547,020	$198,401
Grape, Wine	213	15,199	$18,049	$155,156	$72,163	$249,419	$242,709	$293,341	$106,393
Cotton	105	7,356	$8,735	$75,093	$34,926	$120,714	$117,466	$141,971	$51,492
Grape	69	2,889	$3,431	$29,492	$13,717	$47,409	$46,134	$55,758	$20,223
TOTAL	7,016	375,673	$446,112	$3,834,995	$1,783,656	$6,164,890	$5,999,028	$7,250,489	$2,629,711

* No difference in cost between Goal 2XL and GoalTender (materials and application costs)

Appendix 2

Economic Analysis of Proposed Regulations and Amendments to Reduce Volatile Organic Compound Emissions

Air Resources Board

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TO: Linda Irokawa-Otani
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THROUGH: Fereidun Feizollahi, Manager
Economic Studies Section
Research Division

FROM: Tom Rosen-Molina
Economic Studies Section

DATE: March 9, 2012

SUBJECT: ECONOMIC ANALYSIS OF PROPOSED REGULATIONS AND AMENDMENTS TO REDUCE VOLATILE ORGANIC COMPOUND EMISSIONS

The Department of Pesticide Regulation (DPR) requested an economic analysis of a proposed regulation. DPR proposes to adopt sections 6883 and 6884 of Title 3, California Code of Regulations. The proposed action would restrict the application of highly volatile organic compound nonfumigant products in the San Joaquin Valley between May 1 and October 31 unless the written recommendation of a licensed pest control advisor is obtained.

The Economic Studies Section (ESS) reviewed the Initial Statement of Reasons and corresponded with staff of the California Department of Food and Agriculture (CDFA), University of California Cooperative Extension (UCCE), and DPR to receive additional information on the proposed regulation. After reviewing material provided by DPR, UCCE, and CDFA, economic research staff has reached agreement with DPR on estimated costs of the proposed regulation.

<u>Summary of Findings</u>

The prohibition of the relevant high-VOC (volatile organic compounds) products on the listed crops could affect nearly 17,000 producers in the San Joaquin NAA. The total cost for producers from using low-VOC products instead of high-VOC products on the relevant crops is estimated to be about $1.58 million annually. The average change in expenditures differs by crop, ranging from an average annual savings of $39 for citrus producers to an average additional annual cost of $359 for almond producers.

ESS economic analysis shows that the adoption of this regulation is unlikely to have a significant cost impact on representative private persons or businesses. The additional costs faced by producers should not significantly affect their operations or have a significant adverse economic impact on the sector.

The economic analysis of the proposed regulation is detailed in the attachment, and estimated costs faced by representative agricultural producers are reported in table 4 of the attachment.

If you have any questions, you can contact me at (916) 323 1509, ffeizoll@arb.ca.gov or Tom Rosen-Molina at (916) 323 1182, trosenmo@arb.ca.gov.

bcc: Bart Croes, RD
Michael Benjamin, RD

ECONOMIC ANALYSIS OF PROPOSED REGULATIONS AND AMENDMENTS TO REDUCE VOLATILE ORGANIC COMPOUND EMISSIONS

Pesticide products containing abamectin, chlorpyrifos, gibberellins, or oxyfluorfen are among the highest nonfumigant VOC contributors in the San Joaquin Valley. Products with lower VOC emissions are available for these active ingredients. DPR proposes to prohibit most uses of high-VOC products containing these active ingredients during May-October, the peak ozone season in California, to achieve the SIP reduction goal for the San Joaquin NAA. The proposed regulation would prohibit application on alfalfa, almond, citrus, cotton, grape, pistachio, and walnut crops. However, due to the low efficacy of low-VOC alternative products on some crops, certain exemptions are noted in the regulation. Low-VOC products would not face restrictions.

These nonfumigant VOC restrictions would only occur if pesticide VOC emissions exceeded a trigger level for the San Joaquin Valley during May-October. The trigger level for the San Joaquin Valley NAA is currently 6,365,000 lbs of emissions between May 1 and October 31 or about 17.2 tons per day. Due to the lag in pesticide use reporting, restrictions would be implemented for an upcoming year if pesticide VOC emissions exceeded the trigger level in a preceding year. DPR expects the limit to be exceeded in 2011, which would trigger a fumigant limit for 2013 in the San Joaquin Valley.

Summary of Methodology

Economic Studies Section of ARB estimated total costs to agricultural producers by county and by crop, using a cost study of low-VOC alternatives conducted by UC Cooperative Extension specialists under contract to CDFA's Office of Pesticide Consultation & Analysis (OPCA). ESS adjusted the average per-acre costs from the UC study to 2010 values according to a producer price index. ESS also estimated average costs per farm within each county by dividing overall county costs by farm number estimates from the National Agricultural Statistics Service.

Estimating the Costs of Switching from High-VOC to Low-VOC Products on a Per-acre Basis

Under contract to the CDFA, the University of California cooperative extension specialists evaluated the cost and efficacy of alternative products with lower VOC emissions for the major pesticides used on selected crops, including alfalfa, almonds, cotton, grapes, pistachios, oranges, and walnuts. Average cost estimates for 2005-2007 are available in the UC study, *Emulsifiable Concentrate Alternatives Analysis*. Table 1 shows the estimates.

Table 1: Estimated Cost Per Acre of Switching from High-VOC to Low-VOC Products, by Crop and Chemical

	Alfalfa	Almond	Citrus	Cotton	Grapes	Pistachio	Walnuts
	($/Acre)						
Abamectin*	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorpyrifos	0.02	10.77	0.00	0.00	6.58	0.00	4.10
Gibberellins	0.00	0.00	-1.40	0.00	1.20	0.00	0.00
Oxyfluorfen	0.00	1.19	1.19	1.19	1.19	1.19	1.19
Total	**0.02**	**11.96**	**-0.21**	**1.19**	**8.97**	**1.19**	**5.29**

* Recently registered low-VOC products not evaluated.
Note: Table grapes, raisin grapes, and wine grapes are grouped together. Per acre costs for oranges are assumed to be representative of all citrus.

Negative values in Table 1 indicate estimated savings, which result from the use of new low-VOC products with lower per-acre costs than existing high-VOC products. For example, gibberellins are growth regulators used primarily on citrus and grapes. UC specialists determined that the range of effective low-VOC alternatives had a lower cost than the high-VOC formulation for citrus applications. The low-emission formulations were also judged to be as efficacious as the high-emission formulations in regulating plant growth. The widespread usage of the high-VOC formulation despite a slightly higher cost is explained by the UC specialists as the result of familiarity with the product and perceived ease of use, since the high-VOC formulations are in a liquid form that allows growers to easily adjust the amount of product per acre. Unfamiliarity with the low-VOC formulation and the difficulty in adjusting pesticide amounts with the dry product have held back usage despite slightly lower costs.

As shown in table 1, almonds face the highest per-acre cost of switching to low-VOC products at nearly $12 per acre. The major portion of this cost increase is the result of low-VOC alternatives to chlorpyrifos. Alternatives to chlorpyrifos also contribute a high portion of the per-acre costs for grapes. Citrus costs are expected to decrease with the switch to low-VOC alternatives due to the lower price of alternatives to gibberellin for citrus. The other crops have per-acre costs of switching that range from about $0.02 for alfalfa to about $5.29 for walnuts.

Costs for low-VOC alternatives to abamectin are not included in the analysis because UC and CDFA specialists indicated that producers can simply switch from an emulsifiable concentrate formulation of the product to a suspension concentrate formulation. The cost and efficacy are estimated to be about the same for both formulations, indicating lack of any negligible effect on producers' costs.

<u>Adjustments to Per-acre Costs for Differences in Efficacy of Low-VOC Oxyfluorfen Products</u>

UCCE and CDFA note that the low-VOC formulation of oxyfluorfen will require the use of an additional herbicide. Low-VOC oxyfluorfen is not as effective as a post-emergence herbicide as the high-VOC formulation, so it is necessary to apply a low dose of a low-VOC post-emergence herbicide such as paraquat, flumioxazin, carfentrazone, glyphosate, or glufosinate to achieve the same level of efficacy. UCCE evaluated costs of these additional post-emergence herbicides, which range from $1.19/acre for glyphosate to $19.30/acre for saflufenacil. For the cost calculations performed below, it is assumed that all tracreage that is treated with low-VOC oxyfluorfen is treated with the lowest cost post-emergence herbicide, glyphosate, at about $1.19 per acre.

Estimating Crop Acreage that will Switch from High-VOC to Low-VOC Products

Data on treated acreage by crop and chemical were provided by DPR. Acreage data include adjustments for the exceptions for chlorpyrifos on cotton for aphids, gibberellins applied at <5 grams/acre, and Section 24c applications. Combined, these exceptions account for about 35,300 acres that do not have to switch to low-VOC products. The estimates in table 2 are based on the assumption that the emissions potential (EP) thresholds for abamectin and gibberellins products are set at the highest level of 35% and 25%, respectively. DPR indicates that these estimates would change little if the lowest EP thresholds were assumed instead.

As shown in table 2, almond acreage would change the most from the switch to low-VOC products, with about 760,000 acres switching to alternative products. A major share of the affected almond acreage (about 425,000 acres) would switch to low-VOC abamectin alternatives which are estimated to have the similar prices as high-VOC abamectin products. About 230,000 acres of almonds would switch to low-VOC oxyfluorfen alternatives. After almonds, grapes would see the next largest shift in acreage, with about 270,000 acres going from high-VOC to low-VOC products. More than 130,000 acres of grapes would shift to low-VOC gibberellins products. Pistachios would see the smallest shift in acreage, with about 52,000 acres switching to low-VOC products.

Table 2: Estimated Treated Acreage that would Switch to Low-VOC Products, by Crop and Chemical

	Alfalfa	Almond	Citrus	Cotton	Grapes	Pistachio	Walnuts
	(1000 acres)						
Abamectin	2.1	424.6	50.2	166.3	115.1	0.1	41.8
Chlorpyrifos	70.5	67.6	20.0	77.0	0.0	0.0	18.1
Gibberellins	0.0	0.0	65.4	0.0	135.6	0.0	0.0
Oxyfluorfen	0.0	235.1	0.8	7.4	18.2	51.5	28.3
Total	**72.6**	**762.6**	**136.4**	**250.7**	**268.9**	**51.6**	**88.2**

Note: Table grapes, raisin grapes, and wine grapes are grouped together. Citrus includes lemons, oranges, tangerines, tangelos and grapefruit.

Estimating Changes in Expenditures from the Switch to Low-VOC Products

ESS calculated changes in total expenditures by chemical and crop by multiplying estimates of treated acreage by the estimated change in per acre costs from the UC study. These expenditures are adjusted from the 2005-2007 average prices by inflating values to 2010 dollars according to the Producer Price Index for "Pesticide, fertilizer, and other agricultural chemical mfg" (see table 3). This index is maintained by the Bureau of Labor Statistics, Department of Labor. (http://data.bls.gov)

Table 3 shows that almonds account for the largest share of the increase in expenditures that would result from switching to low-VOC products. Expenditures for almond producers would increase by more than $1.24 million, or nearly 80 percent of the total estimated increase in expenditures. Chlorpyrifos alternatives are responsible for about $900 million of the increased expenditures on almonds, while oxyflurofen alternatives (and the associated post-emergence herbicides) will raise almond expenditures by about $345 million. Low-VOC alternatives for grapes add another $227,000 to total expenditures, with gibberellins accounting for more than $200,000 of this figure. Alfalfa and cotton both face relatively small increases in expenditures of about $1,700 and $10,800, respectively. Due to lower estimated costs for gibberellins alternatives for citrus, expenditures on citrus are expected to decrease by about $112,000 in the San Joaquin NAA.

Table 3: Total Change in Expenditures for All Producers in the San Joaquin NAA from Switching from High-VOC to Low-VOC Products, by Crop and Chemical

	Alfalfa	Almond	Citrus	Cotton	Grapes	Pistachio	Walnuts
	(1000 dollars)						
Abamectin	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chlorpyrifos	1.7	897.5	0.0	0.0	0.0	0.0	91.7
Gibberellins	0.0	0.0	-112.8	0.0	200.6	0.0	0.0
Oxyfluorfen	0.0	344.9	1.2	10.8	26.7	75.5	41.6
Total	**1.7**	**1,242.3**	**-111.7**	**10.8**	**227.3**	**75.5**	**133.3**

Note: Table grapes, raisin grapes, and wine grapes are grouped together. Citrus includes lemons, oranges, tangerines, tangelos and grapefruit.

Changes in average expenditures faced by producers in the San Joaquin Valley NAA are calculated by dividing total expenditures by the estimated number of farms for each crop (see table 4). When counting farms, the San Joaquin NAA is considered to include all of Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus and Tulare counties. Data on number of farms by crop and county is available from the 2007 USDA *Census of Agriculture*. (http://www.agcensus.usda.gov/Publications/2007/index.asp) More recent data on the number of producers by crop and county are not readily available.

Table 4 shows changes in average expenditures from switching to low-VOC products for the affected crops in the San Joaquin NAA. There are more than 3,400 almond producers in the region, and they are expected to face an average increase in expenditures of about $360 per year. Grape producers face the second largest total increase in expenditures, but the relatively high number of producers means that the average increase in expenditures is estimated to be around $50 per year. Pistachio producers face a lower total increase in expenditures, but since there are fewer than 900 producers in the region, the average annual increase in expenditures is about $87.

Average expenditures are expected to fall by about $40 for citrus producers due to the lower prices for low-VOC alternatives. Increases in average cotton and alfalfa expenditures are relatively low, at about $14 and $1, respectively.

Table 4: Total and Average Change in Expenditures for All Producers in the San Joaquin NAA from Switching from High-VOC to Low-VOC Products, by Crop

	Total change in expenditures (1000 dollars)	Estimated number of farms	Average change in expenditures (dollars)
Alfalfa	1.7	1,939	1
Almond	1,242.3	3,462	359
Citrus	-111.7	2,872	-39
Cotton	10.8	798	14
Grapes	227.3	4,512	50
Pistachio	75.5	871	87
Walnuts	133.3	2,470	54
Total	**1,579.2**	**16,924**	**93**

Note: Table grapes, raisin grapes, and wine grapes are grouped together. Citrus includes lemons, oranges, tangerines, tangelos and grapefruit.

Assumptions Made by ESS in Conducting the Economic Analysis

In estimating the costs faced by agricultural producers, it is assumed that use of the low-VOC alternatives will cause no change in producers' yields. Cost estimates in the UCD study are adjusted to account for differences in efficaciousness on a per acre basis. Therefore, in using those cost estimates, this analysis includes only the estimated costs of switching from a high-VOC to a low-VOC regimen of products, and does not account for any other costs that may arise. The cost to producers of obtaining the written recommendation of a licensed pest control advisor (PCA) is considered to be negligible. Most producers already employ a PCA and the largest operations often have a PCA on their payroll. There is little, if any, marginal cost for PCAs to provide written recommendation to use the relevant products.

Alternatives to the Proposed Regulation

DPR has identified several alternatives to the proposed regulatory action. DPR could deny or cancel registrations for high-VOC products and limit registrations to low-VOC products statewide, year-round. This would extend the costs outlined above to agricultural producers across the state and increase aggregate costs substantially. Alternatively, DPR could reclassify the active-ingredients in high-VOC products as restricted materials, which means that high-VOC products would undergo the permitting process and would be evaluated by individual agricultural commissioners for use within each county. This process would limit costs associated with switching from high-VOC to low-VOC products to counties that are close to meeting the VOC trigger level. However, administrative costs for agricultural commissioners would be increased across the state and unnecessary regulatory burden would be placed on growers across the state, who would need to obtain a restricted materials permit to use the high-VOC products.

Discussion of Results

ESS's initial determination is that the lowest cost option is the one that prohibits the use of certain nonfumigant high-VOC products in the San Joaquin Valley NAA during May-October, with exceptions. The alternatives would not lessen any adverse statewide impacts, including impacts on small businesses.

The results of the analysis are summarized in tables 3 and 4. The prohibition of the relevant high-VOC products on the listed crops could affect nearly 17,000 producers in the San Joaquin NAA. This estimate should be considered an upper bound because it includes all producers of the listed crops in Kern County, whereas the San Joaquin NAA includes only a portion of Kern County. Sub-county data on the number of producers are not readily available.

It is difficult to estimate the share of farms in the San Joaquin NAA that can be classified as small businesses because sub-state estimates of revenue distribution by crop are not readily available. Statewide, the share of farms that have annual gross receipts of less than $1 million is about 93 percent and the share in the San Joaquin NAA should be similar. Applying this share to the San Joaquin NAA, approximately 15,740 of the affected farms would be classified as small businesses.

Conclusions

The total cost for producers from using low-VOC products instead of high-VOC products on the relevant crops is estimated to be about $1.58 million annually. The average change in expenditures differs by crop, ranging from an average annual savings of $39 for citrus producers to an average additional annual cost of $359 for almond producers. These representative costs are given in table 4. The additional costs faced by producers should not significantly affect their operations or have a significant adverse economic impact on the sector.

ESS has made an initial determination that the adoption of this regulation is unlikely to have a significant cost impact on representative private persons or businesses. Costs may fluctuate as pesticide product prices change, but in the long-run, it is likely that prices will fall after newer low-VOC products have been on the market for some time. If the emissions trigger level for the San Joaquin Valley NAA is not exceeded, producers would face no high-VOC pesticide restrictions and thus no additional costs.

Appendix 3

Estimated Number of Pesticide Applications for Major Crops that Will Switch from High-VOC Products to Low-VOC Products

Table 3-1. Estimated **alfalfa** applications in the SJV during May-October that will switch from high-VOC products to low-VOC products, if high-VOC prohibitions are triggered. Estimates based on 2010 pesticide use reports.

	Abamectin	Chlorpyrifos	Gibberellins	Oxyfluorfen	Sum
Alfalfa total applications					
Number of applications	142	3,535	0	2	3,679
Acres treated	10,318	226,968	0	9	237,295
Pounds A.I.	114	114,295	0	1	114,410
Pounds VOC	3,163	115,270	0	3	118,436
Alfalfa applications that used high-VOC products and will switch to low-VOC, if trigggered					
Number of applications	37	1,080	0	0	1,117
Acres treated	2,098	70,495	0	0	72,593
Pounds A.I.	23	37,734	0	0	37,757
Pounds VOC	664	49,487	0	0	50,151
Alfalfa applications that used low-VOC products					
Number of applications	0	2,455	0	2	2,457
Acres treated	0	156,474	0	9	156,483
Pounds A.I.	0	76,561	0	1	76,562
Pounds VOC	0	65,783	0	3	65,786
Alfalfa applications that used high-VOC products for an exception					
Number of applications	105	0	0	0	105
Acres treated	8,220	0	0	0	8,220
Pounds A.I.	91	0	0	0	91
Pounds VOC	2,499	0	0	0	2,499
Alfalfa% that used high-VOC products and will switch to low-VOC					
Percent of applications	26	31	0	0	30
Percent of acres treated	20	31	0	0	31
Percent of pounds AI	21	33	0	0	33

Table 3-2. Estimated **almond** applications in the SJV during May-October that will switch from high-VOC products to low-VOC products, if high-VOC prohibitions are triggered. Estimates based on 2010 pesticide use reports.

	Abamectin	Chlorpyrifos	Gibberellins	Oxyfluorfen	Sum
Almond total applications					
Number of applications	8,396	1,410	0	5,138	14,944
Acres treated	622,600	102,735	0	292,073	1,017,408
Pounds A.I.	7,089	186,266	0	56,779	250,134
Pounds VOC	208,145	174,546	0	139,936	522,628
Almond applications that used high-VOC products and will switch to low-VOC, if trigggered					
Number of applications	6,364	813	0	4,153	11,330
Acres treated	424,620	67,612	0	235,127	727,359
Pounds A.I.	7,067	123,754	0	46,509	177,329
Pounds VOC	200,801	145,837	0	124,308	470,946
Almond applications that used low-VOC products					
Number of applications	2,028	595	0	316	2,939
Acres treated	197,887	35,100	0	21,668	254,656
Pounds A.I.	21	62,503	0	5,397	67,922
Pounds VOC	7,307	28,701	0	1,107	37,114
Almond applications that used high-VOC products for an exception					
Number of applications	4	2	0	669	675
Acres treated	93	23	0	35,278	35,393
Pounds A.I.	1	9	0	4,873	4,883
Pounds VOC	37	8	0	14,522	14,567
Almond% that used high-VOC products and will switch to low-VOC					
Percent of applications	76	58	0	81	76
Percent of acres treated	68	66	0	81	71
Percent of pounds AI	100	66	0	82	71

Table 3-3. Estimated **citrus** applications in the SJV during May-October that will switch from high-VOC products to low-VOC products, if high-VOC prohibitions are triggered. Estimates based on 2010 pesticide use reports.

	Abamectin	Chlorpyrifos	Gibberellins	Oxyfluorfen	Sum
Citrus total applications					
Number of applications	1,648	2,257	2,911	32	6,848
Acres treated	52,034	62,658	68,513	1,077	184,282
Pounds A.I.	833	199,790	5,098	439	206,160
Pounds VOC	22,035	146,869	116,312	1,114	286,330
Citrus applications that used high-VOC products and will switch to low-VOC, if trigggered					
Number of applications	1,620	746	2747	21	5,134
Acres treated	50,177	19,957	64828	795	135,757
Pounds A.I.	833	71,439	4913	383	77,568
Pounds VOC	21,962	83,228	114,783	1,103	221,076
Citrus applications that used low-VOC products					
Number of applications	28	1,364	73	11	1,476
Acres treated	1,857	38,530	1208	282	41,877
Pounds A.I.	0	121,021	117	56	121,194
Pounds VOC	73	55,263	10	11	55,357
Citrus applications that used high-VOC products for an exception					
Number of applications	0	147	91	0	238
Acres treated	0	4,170	2477	0	6,647
Pounds A.I.	0	7,330	68	0	7,398
Pounds VOC	0	8,378	1,519	0	9,897
Citrus% that used high-VOC products and will switch to low-VOC					
Percent of applications	98	33	94	66	75
Percent of acres treated	96	32	95	74	74
Percent of pounds AI	100	36	96	87	38

Table 3-4. Estimated **cotton** applications in the SJV during May-October that will switch from high-VOC products to low-VOC products, if high-VOC prohibitions are triggered. Estimates based on 2010 pesticide use reports.

	Abamectin	Chlorpyrifos	Gibberellins	Oxyfluorfen	Sum
Cotton total applications					
Number of applications	2,341	881	0	131	3,353
Acres treated	166,292	125,049	0	8,944	300,285
Pounds A.I.	1,528	114,285	0	3,572	119,385
Pounds VOC	44,359	128,349	0	8,670	181,379
Cotton applications that used high-VOC products and will switch to low-VOC, if trigggered					
Number of applications	2,341	482	0	105	2,928
Acres treated	166,292	76,981	0	7,356	250,629
Pounds A.I.	1,528	72,081	0	3,108	76,717
Pounds VOC	44,359	84,401	0	8,576	137,337
Cotton applications that used low-VOC products					
Number of applications	0	78	0	26	104
Acres treated	0	11,031	0	1,588	12,619
Pounds A.I.	0	7,903	0	464	8,368
Pounds VOC	0	3,976	0	94	4,069
Cotton applications that used high-VOC products for an exception					
Number of applications	0	321	0	0	321
Acres treated	0	37,037	0	0	37,037
Pounds A.I.	0	34,300	0	0	34,300
Pounds VOC	0	39,972	0	0	39,972
Cotton% that used high-VOC products and will switch to low-VOC					
Percent of applications	100	55	0	80	87
Percent of acres treated	100	62	0	82	83
Percent of pounds A.I.	100	63	0	87	64

Table 3-5. Estimated **grape** applications in the SJV during May-October that will switch from high-VOC products to low-VOC products, if high-VOC prohibitions are triggered. Estimates based on 2010 pesticide use reports.

	Abamectin	Chlorpyrifos	Gibberellins	Oxyfluorfen	Sum
Grape total applications					
Number of applications	2,150	163	7,479	344	10,136
Acres treated	115,109	22,291	314,476	20,049	471,925
Pounds A.I.	2,038	41,623	11,062	5,851	60,574
Pounds VOC	55,128	19,115	115,825	15,665	205,732
Grape applications that used high-VOC products and will switch to low-VOC, if triggered					
Number of applications	2,150	1	2057	286	44,94
Acres treated	115,109	3	77196	18,228	210,536
Pounds A.I.	2,038	3	4109	5,208	11,358
Pounds VOC	55,128	3	89,208	15,537	159,877
Grape applications that used low-VOC products					
Number of applications	0	162	2,207	58	2,247
Acres treated	0	22,288	113,961	1,820	138,069
Pounds A.I.	0	41,620	5,793	644	48,057
Pounds VOC	0	19,111	487	127	19,726
Grape applications that used high-VOC products for an exception					
Number of applications	0	0	3,215	0	3,215
Acres treated	0	0	123,319	0	123,319
Pounds A.I.	0	0	1,160	0	1,160
Pounds VOC	0	0	26,129	0	26,129
Grape% that used high-VOC products and will switch to low-VOC					
Percent of applications	100	1	28	83	44
Percent of acres treated	100	0	25	91	45
Percent of pounds A.I.	100	0	37	89	19

Table 3-6. Estimated **pistachio** applications in the SJV during May-October that will switch from high-VOC products to low-VOC products, if high-VOC prohibitions are triggered. Estimates based on 2010 pesticide use reports.

	Abamectin	Chlorpyrifos	Gibberellins	Oxyfluorfen	Sum
Pistachio total applications					
Number of applications	1	0	0	770	771
Acres treated	70	0	0	52,479	52,549
Pounds A.I.	2	0	0	17,029	17,031
Pounds VOC	58	0	0	44,672	44,730
Pistachio applications that used high-VOC products and will switch to low-VOC, if trigggered					
Number of applications	1	0	0	754	755
Acres treated	70	0	0	51,481	51,551
Pounds A.I.	2	0	0	16,517	16,519
Pounds VOC	58	0	0	44,561	44,619
Pistachio applications that used low-VOC products					
Number of applications	0	0	0	16	16
Acres treated	0	0	0	998	998
Pounds A.I.	0	0	0	512	512
Pounds VOC	0	0	0	111	111
Pistachio applications that used high-VOC products for an exception					
Number of applications	0	0	0	0	0
Acres treated	0	0	0	0	0
Pounds A.I.	0	0	0	0	0
Pounds VOC	0	0	0	0	0
Pistachio% that used high-VOC products and will switch to low-VOC					
Percent of applications	100	0	0	98	98
Percent of acres treated	100	0	0	98	98
Percent of pounds A.I.	100	0	0	97	97

Table 3-7. Estimated **walnut** applications in the SJV during May-October that will switch from high-VOC products to low-VOC products, if high-VOC prohibitions are triggered. Estimates based on 2010 pesticide use reports.

	Abamectin	Chlorpyrifos	Gibberellins	Oxyfluorfen	Sum
Walnut total applications					
Number of applications	1,260	1,301	0	1,078	3,639
Acres treated	42,120	40,124	0	28,890	111,134
Pounds A.I.	719	78,154	0	5,285	84,158
Pounds VOC	19,630	58,575	0	13,966	92,170
Walnut applications that used high-VOC products and will switch to low-VOC, if trigggered					
Number of applications	1,248	549	0	1,053	2,850
Acres treated	41,775	18,147	0	28,343	88,266
Pounds A.I.	719	33,328	0	5,086	39,133
Pounds VOC	19,618	38,244	0	13,766	71,628
Walnut applications that used low-VOC products					
Number of applications	12	752	0	23	787
Acres treated	345	21,976	0	520	22,842
Pounds A.I.	0	44,826	0	138	44,965
Pounds VOC	11	20,331	0	32	20,374
Walnut applications that used high-VOC products for an exception					
Number of applications	0	0	0	2	2
Acres treated	0	0	0	26	26
Pounds A.I.	0	0	0	60	60
Pounds VOC	0	0	0	168	168
Walnut% that used high-VOC products and will switch to low-VOC					
Percent of applications	99	42	0	98	78
Percent of acres treated	99	45	0	98	79
Percent of pounds A.I.	100	43	0	96	46