

# Emulsifiable Concentrate Alternatives Analysis

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**March, 2011**

**Revised March, 2012**

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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, *Acyrtosiphon 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). Lorsban 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 than \$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 replace 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** (Poast 1.5EC/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 strongly 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 Sandea 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
<b>VOC Producing Pesticide</b>	<b>Lorsban 4E</b>	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%	
<b>VOC Producing Pesticide</b>	<b>Dimethoate 2.67 EC, Dimethoate 4E and others</b>	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 <sup>a</sup>			Months of appls.	Rate form ac/ appl <sup>b</sup>	% control
			2005	2006	2007			
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%

<sup>a</sup> Use rates from 2005 to 2007 pesticide use report data.

<sup>b</sup> 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		2006		2007	
		Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	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%

<sup>a</sup> 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. apps.	Months apps.	Rate form ac/ appl. <sup>a</sup>	Appl. method	Percent control <sup>b</sup>
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, Alfalfa weevil complex	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, Alfalfa weevil complex	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, Alfalfa weevil complex	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%

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

<sup>b</sup> 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 <sup>a</sup>
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

<sup>a</sup> 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 <sup>a</sup>			
					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

<sup>a</sup> 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. apps.	Months apps.	Rate form ac/ appl <sup>a</sup>	Appl method	% control <sup>b</sup>
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%

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

<sup>b</sup> Compared to Dimethoate 2.67 EC, Dimethoate 4E and others.

<sup>c</sup> 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 <sup>a</sup>
	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

<sup>a</sup> 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	<u>Replacement cost<sup>a</sup></u>		
					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

<sup>a</sup> 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 <sup>1</sup> (%)	Quality change <sup>2</sup> (high, % medium, low, none) change price <sup>3</sup>	
<b>VOC Producing Pesticide(s)</b>	<b>Velpar 2WDL</b>	<b>2.1</b>	<b>Contact and soil residual activity</b>	<b>10-30%</b>	<b>High</b>	<b>30-60%</b>
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			
<b>VOC Producing Pesticide(s)</b>	<b>Poast 1.5EC</b>	<b>2.2</b>	<b>No soil residual</b>	<b>10-30%</b>	<b>High</b>	<b>30-50%</b>
Alternative 1	Select Max 1E	3.3	New formulation/ no soil residual			
Alternative 2	Raptor 1E	3.7	Long soil residual			
<b>VOC Producing Pesticide(s)</b>	<b>Select 2EC</b>	<b>2.3</b>		<b>10-30%</b>	<b>High</b>	<b>30-50%</b>
Alternative 1	Select Max 1E	3.3	New formulation/ no soil residual			
<b>VOC Producing Pesticide(s)</b>	<b>Eptam 7-E</b>	<b>2.4</b>		<b>10-40%</b>	<b>Medium</b>	<b>10-50%</b>
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			

<sup>1</sup>Yield and Stand Loss = Stand loss due to Weed Competition

<sup>2</sup>Quality Change = Lowering of forage quality due to excessive weeds in hay

<sup>3</sup>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 <sup>a</sup>			Months of appls.	Rate form ac/ appl <sup>b</sup>	% control
			2005	2006	2007			
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%

<sup>a</sup> Use rates from 2005 to 2007 pesticide use report data.

<sup>b</sup> 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

Chemical name	Trade name	2005		2006		2007	
		Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	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

<sup>a</sup> 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. <sup>a</sup>	Appl. method	Percent control <sup>b</sup>
Metribuzin	Sencor 75 DF	Broadleaf weeds and	1	Nov. – Jan.	3.33 lb/ac	Ground/Air	> 80%
Hexazinone	Velpar 75 DF	common groundsel	1	Nov. – Jan.	1.15 lb/ac	Ground/Air	> 90%
Fumioxazin	Chateau		2	Nov. – Jan.	0.125 lb/ac	Ground/Air	> 80%

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

<sup>b</sup> 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 <sup>a</sup>
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

<sup>a</sup> 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			
				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

<sup>a</sup> 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 <sup>a</sup>	Appl method	Percent control <sup>b</sup>
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%

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

<sup>b</sup> Compared to Poast 1.5 EC.

<sup>c</sup> 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 <sup>a</sup>
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

<sup>a</sup> 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 <sup>a</sup>		
					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)

<sup>a</sup> 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 <sup>a</sup>		
					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 <sup>b</sup>		(1,653,148)	(2,053,894)	(1,161,104)

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

**Table 22.** Alternative herbicides to Eptam 7-E - Application Details

Chemical name	Trade name	Pest(s) controlled	No. appls.	Months appls.	Rate form ac/ appl <sup>a</sup>	Appl method	Percent control <sup>b</sup>
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%

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

<sup>b</sup> 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 <sup>a,b</sup>	Total material cost/ac	Total material & appl. cost/ac <sup>a,b</sup>
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

<sup>a</sup> Application cost of ground/air speed sprayer is \$10.50/ac.

<sup>b</sup> 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 <sup>a</sup>		
					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

<sup>a</sup> 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 leaf-footed bug, *Leptoglossus chlypealis*, 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 turkestanii*, 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<sub>2</sub>O (Table 1). Prowl H<sub>2</sub>O has recently been registered in California for use in almonds and other crops. Prowl H<sub>2</sub>O 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<sub>2</sub>O 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<sub>2</sub>O 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<sub>2</sub>O 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, Sufflan A.S. (Table 1), has an EP of 39. Sufflan 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). Sufflan A.S. was applied to 17,278, 18,111, and 11,262 acres of almonds in 2005, 2006, and 2007, respectively. Sufflan 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, Sufflan 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 (Sufflan A.S.) is used on less than 3% of the almond acres (Table 2). The new dry flowable formulation of oryzalin (Sufflan Dry Flowable) controls the same spectrum of weeds and is the most likely product to replace Sufflan A.S. However, the cost of the Sufflan Dry Flowable is \$7.03 more expensive per acre than Sufflan 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 (Sufflan A.S.) will be around \$100,000 per year (Table 12). The elimination of Sufflan A.S. and the replacement with Sufflan 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 Sufflan 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). Lorsban 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 (Metcalf 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 (Metcalf 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 bifentazate (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 bifentazate (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 spiroticlofen (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)
<b>Herbicides</b>				
<b>VOC Producing Herbicide</b>	<b>Oxyfluorfen (Goal 2XL)</b>	<b>2.1</b>	<b>0%</b>	<b>none</b>
Alternative 1	Oxyfluorfen (GoalTender)	4.1	0%	none
Alternative 2	Simazine (Princep Caliber 90)	4.2	0%	none
<b>VOC Producing Herbicide</b>	<b>Pendimethalin (Prowl 3.3)</b>	<b>2.2</b>	<b>0%</b>	<b>none</b>
Alternative 1	Pendimethalin (Prowl H <sub>2</sub> O)	7.1	0%	none
Alternative 2	Simazine (Princep Caliber 90)	7.2	0%	none
<b>VOC Producing Herbicide</b>	<b>Oryzalin (Surflan A.S.)</b>	<b>2.3</b>	<b>0%</b>	<b>none</b>
Alternative 1	Oryzalin (Surflan Dry Flowable)	10.1	0%	none
Alternative 2	Simazine (Princep Caliber 90)	10.2	0%	none
<b>VOC Producing Herbicide</b>	<b>Glyphosate (Gly-Flo, Glyfos, Gly-4 herbicide)</b>	<b>2.4</b>	<b>0%</b>	<b>none</b>
Alternative 1	Glyphosate (Glyphos, Roundup Original, Roundup Ultramax, Roundup Weathermax, Glyphomate 41, Touchdown)	13	0%	none
<b>Insecticides</b>				
<b>VOC Producing Insecticide</b>	<b>Chlorpyrifos (Lorsban 4E or Nufos 4E)</b>	<b>2.5</b>	<b>0%</b>	<b>none</b>
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	<i>Bacillus thuringiensis</i> ssp. <i>kurstaki</i> (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

		<b>Miticides</b>		
<b>VOC Producing Pesticide</b>	<b>Abamectin (Agri-Mek 0.15EC)</b>	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 <sup>a</sup>			Months of appls.	Rate formulated / acre/ application <sup>b,c</sup>	Percent control
			2005	2006	2007			
<b>Herbicides</b>								
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, Glyphos, Gly-4 herbicide	Broadleaf and grass weeds	50,042	3,832	9,898	Year-round	33 oz/ac	95
<b>Insecticide</b>								
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
<b>Miticide</b>								
6) Abamectin	Agri-Mek 0.15EC	Web spinning mites	285,937	375,630	430,813	Mar.- Aug.	7.8 oz/ac	100

<sup>a</sup> Use rates (acres treated with 20+ EP value) from 2005 - 2007 pesticide use report data (California Department of Pesticide Regulation, 2005 to 2007).

<sup>b</sup> Formulated amount of herbicides based on 2006 pesticide use report data i.e. active ingredient/ac modified to formulated amount/ac.

<sup>c</sup> 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

Chemical name	Trade name	2005		2006		2007	
		Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	Percent
<b>Herbicides</b>							
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%
<b>Insecticide</b>							
Chlorpyrifos	Lorsban 4E	319.3	19.8%	635.7	27.6%	487.8	21.7%
<b>Miticide</b>							
Abamectin	Agri-Mek 0.15EC	95.1	5.9%	122.1	5.3%	128.0	5.7%

<sup>a</sup> 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 <sup>a</sup>	Predominate Application Method	% control <sup>b</sup>
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

<sup>a</sup> 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).

<sup>b</sup> 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 <sup>a</sup>
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

<sup>a</sup> 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 <sup>a</sup>		
					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

<sup>a</sup> 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 <sup>a</sup>	Predominate Application Method	% control <sup>b</sup>
Alternative 1	Prowl H <sub>2</sub> O	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

<sup>a</sup> 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).

<sup>b</sup> 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 <sup>a</sup>	Total material cost/ac	Total material & appl. cost/ac <sup>a</sup>
Pendimethalin	Prowl H <sub>2</sub> O	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

<sup>a</sup> 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 <sup>a</sup>		
					2005	2006	2007
Broadleaf and grass weeds	Alternative 1	Prowl H <sub>2</sub> O	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

<sup>a</sup> 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 <sup>a</sup>	Predominate Application Method	% control <sup>b</sup>
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

<sup>a</sup> 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).

<sup>b</sup> 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 <sup>a</sup>
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

<sup>a</sup> 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 <sup>a</sup>		
					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

<sup>a</sup> 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 <sup>a</sup>	Predominate Application Method	% control <sup>b</sup>
Alternative 1	Glyphos, Roundup Original, Roundup Ultramax, etc.	Broadleaf and grass weeds	3	Year-round	33 oz/ac	Ground	95

<sup>a</sup> 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).

<sup>b</sup> 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 <sup>a</sup>	Total material cost/ac	Total material & appl. cost/ac <sup>a</sup>
Glyphosate	Glyphos, Roundup Original, Roundup Ultramax, etc.	0.37	fl.oz	33.00	Ground	12.09	39.09

<sup>a</sup> 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 <sup>a</sup>		
					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

<sup>a</sup> 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 <sup>c</sup>	Number of Applications	Months of application(s)	Rate Formulated Product/Acre/ Application <sup>a</sup>	Predominate Application Method	% control <sup>b</sup>
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 <sup>d</sup>	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 <sup>f</sup>	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 <sup>g</sup>	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 <sup>g</sup>	Ants	1	July-Sept	1 lb/ac	Ground	100
Alternative 14	Esteem Ant Bait <sup>g</sup>	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

<sup>a</sup> 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).

<sup>b</sup> Compared to Lorsban 4E

<sup>c</sup> Expected to be canceled by 2010, Brigade 10WP provides superior control of NOW compared to Lorsban 4E and other alternatives

<sup>d</sup> Controls low to moderate NOW populations

<sup>e</sup> NOW = Navel orange worm; PTB = Peach twig borer; TB = Twig borers; SJS = San Jose Scale; OFM = Oriental fruit moth; WSM = Web spinning mites

<sup>f</sup> Do not apply more than once/season on foliage. This material may be phytotoxic to some almond varieties when used in season.

<sup>g</sup> 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 <sup>a</sup>
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 <sup>d</sup>	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
<i>Bacillus thuringiensis</i>	Dipel DF			1.0	Ground		
		15.32	lb			15.32	24.32
Spinosad	Success 2SC	7.0	fl oz	5.7	Ground	39.90	48.90
Pyriproxyfen	Seize 35WP <sup>g</sup>	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 <sup>g</sup>	15.46	lb	1.0	Ground	15.46	24.46
Pyriproxyfen	Esteem Ant Bait <sup>g</sup>	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

<sup>a</sup> 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 <sup>a</sup>		
					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

<sup>a</sup> 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

<b>Alternative</b>	<b>Trade Name</b>	<b>Pest(s) controlled</b>	<b>Number of Applications</b>	<b>Months of application(s)</b>	<b>Rate Formulated Product/Acre/ Application <sup>a</sup></b>	<b>Predominate Application Method</b>	<b>% control <sup>b</sup></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

<sup>a</sup> 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).

<sup>b</sup> 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 <sup>a</sup>	Total material cost/ac	Total material & appl. cost/ac <sup>a</sup>
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

<sup>a</sup> 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 <sup>a</sup>		
					2005	2006	2007
Web-spinning mites	Alternative 1	Omite 30WP	121.70	30	10,439,388	13,714,026	15,728,724
Web-spinning mites	Alternative 2	Kanemite 15SC	14.02	5	200,385	263,242	301,914
Web-spinning mites	Alternative 3	Acramite 50WS	13.84	10	395,794	519,947	596,331
Web-spinning mites	Alternative 4	Savey 50DF	116.59	30	10,001,047	13,138,185	15,068,288
Web-spinning mites	Alternative 5	Apollo SC	58.33	5	833,921	1,095,506	1,256,445
Web-spinning 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

<sup>a</sup> 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 its 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. 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 Warrior 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 zyllostella*) 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 (chloranthraniliprole [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 (Warrior 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 (Warrior 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 <sup>a</sup>			Months of application	Rate Formulated Product/Acre/ Application <sup>b</sup>	% 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

<sup>a</sup> Use rates from 2006 PUR data

<sup>b</sup> 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 <sup>a</sup>	Percent	Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	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

<sup>a</sup> 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 <sup>a</sup>	Application Method	% control
DCPA	Dacthal 75W	purslane	1	Year-round	4.38 lb/ac	ground	80
		burning nettle					40
		pigweed					80
		shepherd's purse					10
		barnyardgrass					90
napropamide	Devrinol 50DF	purslane	1	Year-round	1.15 lb/ac	ground	80
		burning nettle					40
		pigweed					80
		shepherd's purse					50
		barnyardgrass					90

<sup>a</sup>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 <sup>a</sup>		
					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 <sup>b</sup>					(26,184)	(25,860)	(21,858)

<sup>a</sup> 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 <sup>a</sup>		
					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 <sup>b</sup>	18,850	17,124	13,444

<sup>a</sup> 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	2005	Replacement cost <sup>a</sup>		
						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 <sup>b</sup>	445,813	371,076	367,365

<sup>a</sup> 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 <sup>a</sup>			Months of application(s)	Rate Formulated Product/Acre/ Application <sup>b</sup>	% control
			2005	2006	2007			
Chlorpyrifos	Lorsban 4E	cutworms, root maggots, symphylans, wireworms	11,353	10,725	10,766	Jan-Dec	2.5 pt	90
Naled Dimethoate	Dibrom 8E	lep. larvae, aphid	15,723	9,790	7,323	Jan-Dec	1.4 pt	85
	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

<sup>a</sup> Use rates from 2006 PUR data.

<sup>b</sup> 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

Chemical name	Trade name	2005		2006		2007	
		Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	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

<sup>a</sup> 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 <sup>a</sup>	Number. Of Applications	Months of application	Rate Formulated Product/Acre/ Application <sup>b</sup>	Predominate Application Method	% control <sup>c</sup>
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

<sup>a</sup> CRSW: cutworms, root maggots, symphylans, wireworms

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

<sup>c</sup> 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 <sup>a</sup>		
					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 <sup>b</sup>	147,369	139,220	139,750

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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 <sup>a</sup>	Predominate Application Method	% control <sup>b</sup>
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	Durivo	lep. larvae, aphids	1	Jan-Dec	10.0 oz	Ground	100
Alternative 8	chlorantraniliprole 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	flubendiamid	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

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

<sup>b</sup> 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 <sup>a</sup>		
					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
	Alternative 12	Proclaim	54.62	0.5	4,294	2,674	2,000
	Alternative 13	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	Fulfill 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 <sup>b</sup>	229,595	142,968	106,942

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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 <sup>a</sup>	Predominate Application Method	% control <sup>b</sup>
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

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

<sup>b</sup> 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 <sup>a</sup>		
					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
Leafminers only	Alternative 11	Radiant 1SC	66.58	2.0	73,162	65,777	60,727
	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 <sup>b</sup>	1,639,508	1,474,006	1,360,850

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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 <sup>a</sup>	Predominate Application Method	% control <sup>b</sup>
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	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	flubendiamid	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

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

<sup>b</sup> 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 <sup>a</sup>		
					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 II 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	Fulfill 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 <sup>b</sup>	203,222	211,874	179,196

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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 <sup>a</sup>	Predominate Application Method	% control <sup>b</sup>
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

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

<sup>b</sup> 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		Replacement cost <sup>a</sup>		
				acrea	age	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	Fulfill 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 <sup>b</sup>	195,758	186,702	169,965	

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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 fenprothrin 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 a 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
<b>VOC Producing Pesticide</b>	<b>Lorsban 4E</b>		
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
<b>VOC Producing Pesticide</b>	<b>Dimethoate 4E</b>		
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
<b>VOC Producing Pesticide</b>	<b>Danitol 2.4EC</b>		
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
<b>VOC Producing Pesticide</b>	<b>Goal 2XL</b>		
Alternative 1	Goal Tender	0%	None
Alternative 2	Chateau SW	0%	None
<b>VOC Producing Pesticide</b>	<b>Gibgro 4LS or ProGibb 4%</b>		
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 <sup>a</sup>			Months of appls.	Rate form ac/ appl <sup>b</sup>	% control
			2005	2006	2007			
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

<sup>a</sup> Use rates from 2005 to 2007 pesticide use report data.

<sup>b</sup> 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

Chemical name	Trade name	2005		2006		2007	
		Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	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

<sup>a</sup> 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. <sup>a</sup>	Appl. method	Percent control <sup>b</sup>	
Chlorpyrifos	Lorsban Advanced	Citricola scale and California red scale	1	May-Oct	12 pt	Ground	100 <sup>c</sup>	
Spirotetramat	Movento		1	May-Oct	10 fl oz	Ground	100	
Buprofezin	Applaud 70DF		1	May-Sep	46.00 oz	Ground	80	
Methidathion	Supracide 25W		1	May-Oct	12.00 lb	Ground	100 <sup>c</sup>	
Carbaryl	Sevin 80S		1	May-Oct	13.25 lb	Ground	80 <sup>c</sup>	
Carbaryl	Sevin XLR Plus		1	May-Oct	10.50 qt	Ground	80 <sup>c</sup>	
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 <sup>c</sup>	
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 <sup>c</sup>	
Carbaryl	Sevin 80S		1	Aug-Sep	13.25 lb	Ground	80 <sup>c</sup>	
Carbaryl	Sevin XLR Plus		1	Aug-Sep	10.50 qt	Ground	80 <sup>c</sup>	
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		

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

<sup>b</sup> Compared to Lorsban 4E.

<sup>c</sup> 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 <sup>a</sup>
<b>Chlorpyrifos</b>	<b>Lorsban 4E</b>	<b>8.64</b>	<b>pt</b>	<b>6.5</b>	<b>Ground</b>	<b>41.60</b>	<b>57.60</b>
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

<sup>a</sup> 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 <sup>a</sup>		
					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 <sup>b</sup>		(1,564,294)	(1,103,555)	(673,164)

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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 <sup>a</sup>	Appl method	% control <sup>b</sup>
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

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

<sup>b</sup> Compared to Dimethoate 4E

<sup>c</sup> 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 <sup>a</sup>
<b>Dimethoate</b>	<b>Dimethoate 4E</b>	<b>6.85</b>	<b>pt</b>	<b>3.00</b>	<b>Ground</b>	<b>20.55</b>	<b>36.55</b>
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

<sup>a</sup> 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 <sup>a</sup>		
					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 <sup>b</sup>		(813,561)	(957,898)	(1,320,598)

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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 <sup>a</sup>	Appl method	% control <sup>b</sup>
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

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

<sup>b</sup> Compared to Dimethoate 4E

<sup>c</sup> 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 <sup>a</sup>
<b>Fenpropathrin</b>	<b>Danitol 2.4EC</b>	<b>1.66</b>	<b>oz</b>	<b>19.70</b>	<b>Ground</b>	<b>32.70</b>	<b>48.70</b>
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

<sup>a</sup> 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 <sup>a</sup>		
					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 <sup>b</sup>		(569,564)	(450,515)	(512,012)

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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. <sup>a</sup>	Appl. method	Percent control <sup>b</sup>
Oxyfluorfen	GoalTender	Broadleaf weeds	1	Mar-Jun	4 pt	Ground	80
Flumioxazin	Chateau SW	Broadleaf weeds	1	Mar-Jun	6 oz	Ground	85

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

<sup>b</sup> 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 <sup>a</sup>
<b>Oxyfluorfen</b>	<b>Goal 2XL</b>	<b>16.48</b>	<b>pt</b>	<b>7</b>	<b>Ground</b>	<b>38.00</b>	<b>54.00</b>
Oxyfluorfen	GoalTender	35.04	pt	4	Ground	46.17	62.17
Flumioxazin	Chateau SW	8.47	oz	6	Ground	16.77	32.77

<sup>a</sup> 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 <sup>a</sup>		
					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 <sup>b</sup>		(40,850)	(43,577)	(33,632)

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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. <sup>a</sup>	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

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

<sup>b</sup> 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 <sup>a</sup>
<b>Gibberellic Acid</b>	<b>Gibgro 4LS/ProGibb 4%</b>	<b>1.67</b>	<b>oz</b>	<b>30.00</b>	<b>Ground</b>	<b>50.40</b>	<b>66.10</b>
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

<sup>a</sup> 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 <sup>a</sup>		
				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 <sup>b</sup>	59,456	67,607	72,078

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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). Lorsban 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 4E 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 silverleaf 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 than \$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<sub>2</sub>O), 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<sub>2</sub>O 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<sub>2</sub>O was \$30.03 (Table 17). If the acreage receiving Treflan was entirely replaced with Prowl H<sub>2</sub>O, it is 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<sub>2</sub>O. Prowl H<sub>2</sub>O 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<sub>2</sub>O 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<sub>2</sub>O is \$30.03 (Table 23). If the acreage receiving Prowl 3.3 EC was completely replaced with Prowl H<sub>2</sub>O, 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 (%)
<b>VOC Producing Pesticide</b>	<b>Lorsban 4E</b>	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 <sup>A</sup>	30	30
<b>VOC Producing Pesticide</b>	<b>Lorsban 4E</b>	5-10 <sup>B</sup>	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
<b>VOC Producing Pesticide</b>	<b>Vydate C-LV</b>	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 <sup>A</sup>	30	30

<sup>A</sup> only useful and applicable during the early portion of the season (not the most critical period).

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

<sup>C</sup> 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 (%)
<b>VOC Producing Pesticide</b>	<b>Vydate C-LV</b>	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 <sup>C</sup>	25	0
Alternative 12 – Lygus bugs	Orthene 75S	15-20	0
<b>VOC Producing Pesticide</b>	<b>Zephyr 0.15EC</b>	0	0
Alternative 1 – spider mites	Oberon 2SC	0	0
Alternative 2 – spider mites	Zeal	0	0
Alternative 3 – spider mites	Temik 15G <sup>C</sup>	10	0
Alternative 4 – spider mites	Acramite 4SC	10-15	0

<sup>A</sup> only useful and applicable during the early portion of the season (not the most critical period)

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

<sup>C</sup> 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 <sup>a</sup>			Months of appls.	Rate form ac/ appl <sup>b</sup>	% control
			2005	2006	2007			
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

<sup>a</sup> Use rates from 2005 to 2007 pesticide use report data.

<sup>b</sup> 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

Chemical name	Trade name	2005		2006		2007	
		Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	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

<sup>a</sup> 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. <sup>a</sup>	Appl. method	Percent control <sup>b</sup>
Fonicamid	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 <sup>A</sup>	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

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

<sup>b</sup> 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 <sup>a</sup>
<b>Chlorpyrifos</b>	<b>Lorsban 4E</b>	<b>8.65</b>	<b>pt</b>	<b>2.00</b>	<b>Ground/ Air</b>	<b>17.30</b>	<b>27.30</b>
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 <sup>A</sup>	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

<sup>a</sup> 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 <sup>a</sup>		
					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 <sup>A</sup>	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

<sup>a</sup> 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. <sup>a</sup>	Appl. method	Percent control <sup>b</sup>
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 <sup>A</sup>	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

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

<sup>b</sup> 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 <sup>a</sup>
<b>Oxamyl</b>	<b>Vydate C-LV</b>	<b>0.94</b>	<b>fl. oz</b>	<b>34.0</b>	<b>Ground/ Air</b>	<b>31.96</b>	<b>40.93</b>
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 <sup>A</sup>	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

<sup>a</sup> 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 <sup>a</sup>			
					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 <sup>A</sup>	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

<sup>a</sup> 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 <sup>a</sup>	Appl method	% control <sup>b</sup>
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

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

<sup>b</sup> 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 <sup>a</sup>
<b>Abamectin</b>	<b>Zephyr 0.15EC</b>	<b>7.22</b>	<b>fl. oz</b>	<b>16.00</b>	<b>Ground/ Air</b>	<b>115.52</b>	<b>124.52</b>
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 <sup>A</sup>	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

<sup>a</sup> 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 <sup>a</sup>		
					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)

<sup>a</sup> 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 (%)
<b>VOC Producing Pesticide</b>	<b>Treflan HFP<sup>a</sup></b>	0	0
Alternative 1 –	Prowl H2O	0	0
<b>VOC Producing Pesticide</b>	<b>Goal 2XL</b>	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
<b>VOC Producing Pesticide</b>	<b>Prowl 3.3EC</b>	0	0
Alternative 1 –	Prowl H2O	0	0

<sup>a</sup> 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 <sup>a</sup>			Months of appls.	Rate form ac/appl <sup>b</sup>	% control
			2005	2006	2007			
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

<sup>a</sup> Use rates from 2005 to 2007 pesticide from Pesticide Use report data, Dept of Pesticide Regulation

<sup>b</sup> 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		2006		2007	
		Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	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

<sup>a</sup> Amount from 2005 to 2007 from Pesticide Use report data, Dept of Pesticide Regulation.

**Table 16.** Alternative herbicides to Treflan HFP<sup>a</sup> - Application Details

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

<sup>a</sup> Treflan 4D, Treflan 4EC, Treflan 4L

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

<sup>c</sup> 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 <sup>a</sup>
<b>Trifluralin</b>	<b>Treflan HFP</b>	<b>4.85</b>	<b>pt</b>	<b>1.50</b>	<b>Ground/ Air</b>	<b>7.28</b>	<b>16.28</b>
Pendimethalin	Prowl H2O	7.01	pt	3.00	Ground/ Air	21.03	30.03

<sup>a</sup> 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 <sup>a</sup>		
					2005	2006	2007
Grasses, pigweed, lambsquarter, purslane	Alternative 1	Prowl H2O	30.03	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 <sup>a</sup>	Appl method	% control <sup>b</sup>
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

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

<sup>b</sup> 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 <sup>a</sup>
<b>Oxyfluorfen</b>	<b>Goal 2XL</b>	<b>17.25</b>	<b>pt</b>	<b>2.00</b>	<b>Ground/ Air</b>	<b>34.50</b>	<b>56.55</b>
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

<sup>a</sup> 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 <sup>a</sup>		
					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, morning glory	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

<sup>a</sup> 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. <sup>a</sup>	Appl. method	Percent control <sup>b</sup>
Pendimethalin	Prowl H2O	grasses, pigweed, lambsquarter, purslane	1	Feb. – Apr.	3 pts.	Ground/Air	99%

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

<sup>b</sup> 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 <sup>a</sup>
<b>Pendimethalin</b>	<b>Prowl 3.3EC</b>	<b>6.41</b>	<b>pt</b>	<b>2.40</b>	<b>Ground/ Air</b>	<b>15.38</b>	<b>24.38</b>
Pendimethalin	Prowl H2O	7.01	pt	3.00	Ground/ Air	21.03	30.03

<sup>a</sup> 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 <sup>a</sup>		
					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

<sup>a</sup> 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, *Pseudococcus 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, Sufflan A.S., has an EP of 39. Sufflan 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 Sufflan 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 (Sufflan 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 Sufflan A.S. (Table 11). The total cost (product + application costs) of Sufflan 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 Sufflan A.S. is replaced by 30% with Princep 4L and 70% with Princep Caliber 90, we estimate that a complete substitution for Sufflan 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<sub>3</sub>, 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 ( $\leq 1$  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
<b>VOC Producing Pesticide</b>	<b>Lorsban 4E</b>	0	
Alternative 1	Lorsban Advanced		None
Alternative 2	Applaud 70DF		None
Alternative 3	Movento		None
<b>VOC Producing Pesticide</b>	<b>Goal 2XL</b>	0	
Alternative 1	GoalTender		None
Alternative 2	Princep 4L		None
Alternative 3	Princep Caliber 90		None
<b>VOC Producing Pesticide</b>	<b>Surflan AS</b>	0	
Alternative 1	Princep 4L		None
Alternative 2	Princep Caliber 90		None
<b>VOC Producing Pesticide</b>	<b>4% liquid concentrate gibberellic acid formulations</b>	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 <sup>a</sup>			Months of appls.	Rate form ac/ appl <sup>b</sup>	% control
			2005	2006	2007			
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	Increase cluster length, reduce berry set, reduce hand- thinning costs,	197,418	176,066	188,829	May – Jun.	23 g/ac	> 90
	Gibgro 4LS	increase berry size and uniformity, reduce berry shrivel						
	ProGibb 4%							

<sup>a</sup> From 2005, 2006 and 2007 pesticide use report data, respectively.

<sup>b</sup> 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

Chemical name	Trade name	2005		2006		2007	
		Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	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

<sup>a</sup> 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 <sup>a</sup>	Appl. method	Percent control <sup>b</sup>
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

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

<sup>b</sup> 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 <sup>a</sup>
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

<sup>a</sup> 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 <sup>a</sup>		
					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 <sup>b</sup>			440,272	500,924	566,428

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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 <sup>a</sup>	Appl method	Percent control <sup>b</sup>
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%

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

<sup>b</sup> 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 <sup>a</sup>	Total material cost/ac	Total material & appl. cost/ac <sup>a</sup>
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

<sup>a</sup> 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 replacement acreage	Replacement cost <sup>a</sup>		
					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 <sup>b</sup>	(2,185,088)	(2,304,847)	(2,075,438)

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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	Formulated Rate/ac <sup>a</sup>	Appl method	Percent control <sup>b</sup>
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%

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

<sup>b</sup> 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 <sup>a</sup>	Total material cost/ac	Total material & appl. cost/ac <sup>a</sup>
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

<sup>a</sup> 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 <sup>a</sup>		
					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 <sup>b</sup>	(899,556)	(1,256,199)	(710,345)

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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 <sup>a</sup>	Appl method	% control <sup>b</sup>
Gibberellins	Gibgro 20% Powder	Increase cluster length, reduce berry	1	May-June	100 g/ac	Ground	100
Gibberellins	ProGibb Plus 2X	set, reduce hand-	1	May-June	100 g/ac	Ground	100
Gibberellins	ProGibb 40%	thinning costs,	1	May-June	50 g/ac	Ground	100
Gibberellins	Gibgro 5% Powder	increase berry size and uniformity, reduce berry shrivel	1	May-June	400 g/ac	Ground	100

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

<sup>b</sup> 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 <sup>a</sup>	Total material cost/ac	Total material & appl. cost/ac <sup>a</sup>
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

<sup>a</sup> 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 <sup>a</sup>		
					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 <sup>b</sup>	236,902	211,279	226,595

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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 californica*), corn earworm (*Helioverpa 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 Fulfill 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 (*Scutigerebella 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 (*Echinochloa crus-galli*) and junglerice (*Echinochloa 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
<b>VOC Producing Insecticide</b>	<b>Dimethoate E267</b>	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
<b>VOC Producing Insecticide</b>	<b>Pounce 3.2EC</b>	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
<b>VOC Producing Insecticide</b>	<b>Warrior</b>	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

<b>VOC Producing Insecticide</b>	<b>Metasystox-R</b>	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
<b>VOC Producing Insecticide</b>	<b>Diazinon AG 500</b>	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

Chemical name	Trade name	Pest(s) controlled	No. acres treated <sup>a</sup>			Months of applis.	Rate form ac/appl <sup>b</sup>	% control
			2005	2006	2007			
Dimethoate	Dimethoate E267	Aphids <sup>2</sup>	85,806	70,660	30,237	Year around	12.0 oz/ac	>80
Permethrin	Pounce 3.2EC	Lep. larvae <sup>1</sup>	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

<sup>a</sup> Use rates from 2005 to 2007 pesticide use report data.

<sup>b</sup> 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

Chemical name	Trade name	2005		2006		2007	
		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

<sup>a</sup> 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 <sup>b</sup>	Appl. method	% control
Imidacloprid	Admire Pro	Aphids <sup>2</sup>	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

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

<sup>b</sup> 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 <sup>a</sup>
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

<sup>a</sup> 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 <sup>a</sup>		
					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

<sup>a</sup> 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 <sup>b</sup>	Appl. method	% control
Permethrin	Pounce 25WP	Lep. larvae <sup>1</sup>	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

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

<sup>b</sup> 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 <sup>a</sup>
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

<sup>a</sup> 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 <sup>a</sup>		
					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

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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 <sup>b</sup>	Appl. method	% control
Spinosad	Success	Lep. larvae <sup>1</sup>	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

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

<sup>b</sup> 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 <sup>a</sup>
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

<sup>a</sup> 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 <sup>a</sup>		
					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

<sup>a</sup> 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 <sup>b</sup>	Appl. method	% control
Imidacloprid	Admire Pro	Aphids <sup>2</sup>	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

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

<sup>b</sup> 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 <sup>a</sup>
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

<sup>a</sup> 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 <sup>a</sup>		
					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

<sup>a</sup> 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 <sup>b</sup>	Appl. method	% control
Imidacloprid	Admire Pro	Aphids <sup>2</sup>	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

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

<sup>b</sup> 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 <sup>a</sup>
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

<sup>a</sup> 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 <sup>a</sup>		
					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

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

**<sup>1</sup> Lep. larvae commonly attacking lettuce include:**

alfalfa looper	<i>Autographa californica</i>
beet armyworm	<i>Spodoptera exigua</i>
cabbage looper	<i>Trichoplusia ni</i>
cutworms	<i>Agrotis ipsilon</i>
granulate cutworm	<i>Feltia subterranea</i>
corn earworm	<i>Helicoverpa zea</i>
tobacco budworm	<i>Heliothis virescens</i>

**<sup>2</sup> Aphids commonly attacking lettuce include:**

foxglove aphid	<i>Aulacorthum solani</i>
green peach aphid	<i>Myzus persicae</i>
lettuce root aphid	<i>Pemphigus bursarius</i>
lettuce aphid	<i>Nasonovia ribis-nigri</i>
potato aphid	<i>Macrosiphum euphorbiae</i>

**Table 19.** VOC Producing Herbicides and Alternatives

	Materials	Yield loss (%)	Quality Change
<b>VOC Producing Pesticide(s)</b>	<b>Prefar4E</b>	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 <sup>a</sup>			Months of applis.	Rate form ac/appl <sup>b</sup>	% control
			2005	2006	2007			
Bensulide	Prefar4E	Purslane, Burning nettle, Pigweed, Barnyardgrass	15,836	18,513	18,064	Year-round	1.40 gal/ac	80 50 80 80

<sup>a</sup> Use rates from 2005 to 2007 pesticide use report data.

<sup>b</sup> 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 <sup>a</sup>			Months of applis.	Rate form ac/appl <sup>b</sup>	% control
			2005	2006	2007			
Bensulide	Prefar4E	Purslane, Burning nettle, Pigweed, Barnyardgrass	21,463	29,882	29,467	Year-round	1.40 gal/ac	80 50 80 80

<sup>a</sup> Use rates from 2005 to 2007 pesticide use report data.

<sup>b</sup> 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		2006		2007	
		Amount	Percent	Amount	Percent	Amount	Percent
Bensulide	Prefar4E	102.3	19.0	135.4	22.7	122.8	21.1

<sup>a</sup> 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 <sup>b</sup>	Appl. method	% control
Pronamide	Kerb 50W	Purslane	1	Year-round	1.2 lb/ac	ground	90
		Nettle					90
		Pigweed					10
Benefin	Balan DF	Barnyardgrass	1	Year-round	1.25 lb/ac	ground	90
		Purslane					80
		Nettle					10
		Pigweed					80
Sethoxydim	Poast	Barnyardgrass	1	Year-round	0.18 gal/ac	ground	80
		Purslane					0
		Nettle					0
		Pigweed					0
Pronamide + Benefin	Kerb 50W + Balan DF	Barnyardgrass	1	Year-round	1.2 lb/ac	ground	95
		Purslane					95
		Pigweed					85
		Barnyardgrass					95

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

<sup>b</sup> 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 <sup>a</sup>
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

<sup>a</sup>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 <sup>a</sup>		
					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

<sup>a</sup> 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 <sup>a</sup>		
					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

<sup>a</sup> 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 4E 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 web-spinning mites are a perennial problem. Agri-Mek 0.15EC is effective against Omite 30W resistant web-spinning mite populations.

There are a number of low EP alternative miticides for control of web-spinning mites (Table 13). These alternatives include: propargite (Omite 30W) with an EP of 1.84, dicofol (Kelthane MF) with an EP of 3.2, bifentazate (Acrامة 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 spiroticlofen (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 web-spinning mites and should be applied at 7 lb/ac. Resistance of web-spinning 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 web-spinning 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. Acrامة 50W is a relatively new miticide and is effective against all motile forms of web-spinning mites. Acrامة 50W should be applied at 14 oz/ac. The use of Acrامة 50W would increase with the elimination of Agri-Mek 0.15EC. However, the higher cost of Acrامة 50W compared to the other alternatives would limit the increase of Acrامة 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 web-spinning 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<sub>2</sub>O (Table 7). Prowl H<sub>2</sub>O 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<sub>2</sub>O 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<sub>2</sub>O instead of Prowl 3.3 EC (Table 3). Prowl H<sub>2</sub>O 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<sub>2</sub>O 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 dinitroaniline 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
<b>VOC Producing Pesticide</b>	<b>Lorsban 4E</b>	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
<b>VOC Producing Pesticide</b>	<b>Prowl 3.3EC</b>	0	
Alternative 1	Prowl H <sub>2</sub> O		None
Alternative 2	Surflan Flowable		None
Alternative 3	Princep 4L and Caliber 90		None
<b>VOC Producing Pesticide</b>	<b>Goal 2XL</b>	0	
Alternative 1	Goal Tender		None
Alternative 2	Rely 200		None
Alternative 3	Gramoxone Inteon		None
Alternative 4	Matrix		None
Alternative 5	Chateau		None
<b>VOC Producing Pesticide</b>	<b>Agri-Mek 0.15EC</b>	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 <sup>a</sup>			Months of appls.	Rate form ac/ appl <sup>b</sup>	% control
			2005	2006	2007			
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

<sup>a</sup> Use rates from 2005 to 2007 pesticide use report data.

<sup>b</sup> 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

Chemical name	Trade name	2005		2006		2007	
		Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	Percent	Amount <sup>a</sup>	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

<sup>a</sup> 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. <sup>a</sup>	Appl. method	Percent control <sup>b</sup>
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 <sup>c</sup>	CM	1	Apr. – Aug.	13.2 oz/ac	Ground	100

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

<sup>b</sup> Compared to Lorsban 4E.

<sup>c</sup> 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 <sup>a</sup>
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
Methoxyfenozone	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

<sup>a</sup> 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 <sup>a</sup>		
					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 <sup>b</sup>	(498,643)	(480,842)	(443,512)

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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 <sup>a</sup>	Appl method	% control <sup>b</sup>
Pendimethalin	Prowl H <sub>2</sub> O	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 <sup>c</sup>	1.60 lb/ac	Ground	>70%

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

<sup>b</sup> Compared to Prowl 3.3EC.

<sup>c</sup> 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 <sup>a</sup>
Pendimethalin	Prowl 3.3EC	39.62	Gal	0.18	Ground	7.20	16.20
Pendimethalin	Prowl H <sub>2</sub> O	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

<sup>a</sup> 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	<u>Replacement cost<sup>a</sup></u>			
					2005	2006	2007	
Foxtail, Watergrass, annual grasses and broadleaf weeds	Alternative 1	Prowl H <sub>2</sub> O	24.60	80	87,377	57,139	26,368	
Foxtail, Watergrass, annual grasses and broadleaf weeds	Alternative 2	Surflan DF 85%	55.91	10	17,601	11,510	5,311	
Foxtail, Watergrass, annual grasses and broadleaf 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 <sup>b</sup>	(38,085)	(24,905)	(11,493)

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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 <sup>a</sup>	Appl method	Percent control <sup>b</sup>
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%

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

<sup>b</sup> 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 <sup>a</sup>	Total material cost/ac	Total material & appl. cost/ac <sup>a</sup>
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

<sup>a</sup> 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 <sup>a</sup>		
					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 <sup>b</sup>	(856,184)	(869,887)	(837,356)

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> 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 <sup>a</sup>	Appl method	% control <sup>b</sup>
Propargite	Omite 30W	Web spinning mites	1	Jun-Aug	7.0 lb/ac	Ground	100
Dicofol	Kelthane MF	Web spinning mites	1	Jun-Aug	64.0 oz/ac	Ground	100
Bifenazate	Acramite 50WP	Web spinning mites	1	Jun-Aug	13.7 oz/ac	Ground	100
Clofentezine	Apollo 1SC	Web spinning mites	1	Jun-Aug	4.8 oz/ac	Ground	100
Hexythiazox	Savey 50WP	Web spinning mites	1	Jun-Aug	5.1 oz/ac	Ground	100
Fenbutatin-oxide	Vendex 50WP	Web spinning mites	1	Jun-Aug	1.7 lb/ac	Ground	100
Spirodiclofen	Envidor 2SC	Web spinning mites	1	Jun-Aug	18.0 oz/ac	Ground	100

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

<sup>b</sup> 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 <sup>a</sup>	Total material cost/ac	Total material & appl. cost/ac <sup>a</sup>
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

<sup>a</sup> 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 <sup>a</sup>		
					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 <sup>b</sup>					376,864	642,882	809,384

<sup>a</sup> Replacement cost was based on estimated number of acres treatment with alternative times the cost of alternative.

<sup>b</sup> Positive number is savings, negative number is increase in costs.