The Economic Importance of Organophosphates in California Agriculture

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APPENDIX

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INTRODUCTION

Entomologically sound pest management programs are a necessary foundation for an economic analysis of the importance of organophosphate (OP) insecticides to California agriculture. OP free insect pest management programs must be unbiased and constructed with clearly understandable parameters and objectives. The economic analysis in this report relied on OP free insect pest management programs constructed by University of California Cooperative Extension (UCCE) entomologists. UCCE entomologists have intimate knowledge of existing programs while at the same time are knowledgeable of new pest management tools that will become available in the near future. In fact, UCCE entomologists are often in the forefront of the development of new pest management tools.

For this analysis, UCCE entomologists developed a “typical” insect pest management program for a commodity or commodities in which they have expertise. The OP free insect pest management programs are constructed for immediate implementation without consideration of the cost of the program or consequence of insecticide resistance. The programs take into account any secondary or occasional pests that may require additional control measures. Also, the UCCE entomologists estimated any increased damage or yield loss above current levels that would result from their OP free insect pest management program.

The UCCE entomologists also developed a more ecologically sound OP free insect pest management program using currently available pest management practices and those emerging technologies that are anticipated to be registered within the next four or five years. Again, the UCCE entomologists accounted for any secondary or occasional pests that may require additional control measures and any increased damage or yield loss above current levels that would result from their more ecologically sound OP free insect pest management program.

Integrated pest management systems are dynamic and are in a constant state of flux as new control methodologies and insecticides are registered and implemented into pest control programs. Since the completion of the OP free insect pest management programs, there have been a number of new insecticides and miticides registered that were not registered at the time of the preparation of the programs. Thus, addenda are provided for those commodities in which new insecticides/miticides have been registered or new control methodologies have been implemented after the initial preparation and analysis. In a few commodities, the newly registered insecticides/miticides will significantly aid the IPM programs by adding new modes of control that may help with resistance management and increase competition among products that potentially may lower costs. These addenda are found at the end of individual OP free insect pest management programs.

ALFALFA HAY

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California produces about 15% of the alfalfa hay in the United States and alfalfa is produced in most counties in the state. The primary growing regions are the Central Valley region, which produces 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. Insect damage results from defoliation from chewing insects and removal of plant fluids from piercing/sucking insects. The defoliating insects include the alfalfa weevil/Egyptian alfalfa weevil complex and lepidopterous larval complex including the alfalfa caterpillar, western yellowstriped armyworm and beet armyworm. The piercing/sucking insects include the pea, blue alfalfa, cowpea and spotted alfalfa aphid complex.

Weevil Species Complex

Alfalfa Weevil (AW), *Hypera postica*
Egyptian Alfalfa Weevil (EAW), *Hypera brunnipennis*

Weevils are major pests of alfalfa hay that can cause substantial losses in all areas of the state. Two very similar weevil species, AW, and the more EAW, differ in distribution and susceptibility to parasitism. Throughout the Central Valley and the desert region, EAW is the more common pest while AW is more prevalent in the cooler production areas of the state. Weevil populations typically reach damaging levels in March and April in the Central Valley. In the southern desert region, weevil activity is usually limited to January through March. While adult weevils will feed on alfalfa, larvae cause the damage. Weevil larvae generally damage the first cutting of the year, which can be February in the desert region and as late as May in the Central Valley. Damage can occur to the second cutting, especially from EAW. Besides defoliation damage, larvae often feed and damage the regrowth that stunts growth and can kill stems.

Control of AW with the parasitic wasp *Bathyplects curculionis* can maintain populations at low levels in the Salinas Valley and parts of the north coast. However, *B. curculionis* does not achieve adequate control in other areas of the state and is not effective for control of EAW. Insecticide applications are often required for weevil control. The key to weevil management is careful monitoring of the population. If spring larval populations exceed 20 larvae per sweep, then an insecticide application is warranted. However, careful attention must be paid to aphid populations since insecticides applied for weevil control often kill natural aphid enemies and may contribute to secondary aphid outbreaks. Insecticides used for control of the weevil complex include carbofuran (Furadan), phosmet (Imidan) and chlorpyrifos (Lorsban). Lorsban also provides aphid control. Other insecticides used for weevil control include permethrin (Pounce), lambda-cyhalothrin (Warrior), cyfluthrin (Baythroid), and malathion (Malathion).

Lepidopterous Larval Complex

Alfalfa Caterpillar (AC) Colias eurtheme Boisduval
Western Yellowstriped Armyworm (WYA), *Spodoptera praefica*
Beet Armyworm (BAW), *Spodoptera exigu*
Alfalfa Looper (AL), *Autographa californica*
Saltmarsh Caterpillar (SC), *Estigmene acrea*

The primary lepidopteran pests that cause economic damage to alfalfa are the AC, WYA and BAW. There are a number of other lepidopterous pests that may cause significant damage; these include the AL, SC and various cutworms. These pests may significantly damage entire fields before the alfalfa reaches maturity, with the most significant damage often occurring to seedlings.

These caterpillars synchronize their development with the hay cutting cycle. Recently cut hay fields are highly attractive for oviposition, particularly for AC. The larvae can complete their development and pupate before the next cutting. Lepidopterous larval pests become important in late spring and summer, although populations can continue to affect fields into the fall months, particularly in the desert region. AC eats large portions of leaves and may completely defoliate entire areas of a field. This makes damage from AC easy to distinguish from that of armyworms, which usually skeletonize foliage leaving the midrib intact. Cutworms cause economic damage to seedling alfalfa fields by cutting off the tops of seedlings at or just above the soil surface. The most important mechanism of control for all of these pests is preserving and encouraging populations of natural enemies. A great variety of general predators, such as lacewings, damsel bugs, bigeyed bugs, spiders, minute pirate bugs, etc., may limit lepidopterous pest numbers, but the most important natural enemies are parasitic wasps including *Apanteles medicaginis*, *Trichogramma semifumatum* and *Hyposoter exiguae*, among others. However, insecticides applied to control aphids and weevils often eliminate the natural enemy complex. A lack of beneficial insects often leads to additional insecticide treatments to control lepidopterous pests. Insecticides used for control of the lepidopteran complex include Bacillus thuringiensis (Bt) for AC and AL, Lannate, Baythroid and Pounce for BAW and WYA. Bt has proven ineffective for control of BAW and WYA.

Aphid Species Complex

Pea Aphid (PA), *Acyrthosiphon pisum*
Blue Alfalfa Aphid (BAA), *Acyrthosiphon kondoi*
Spotted Alfalfa Aphid (SAA), *Therioaphis maculata*
Cowpea Aphid (CA), *Aphis craccivora* Koch

The principal aphid pests of alfalfa include the PA and the BAA. The SAA was once the most significant pest of alfalfa hay in California, but it is no longer a major concern due to the introduction of beneficial insects and resistant alfalfa hay cultivars. A relatively recent pest, the CA, has caused significant damage in the desert region and parts of the Central Valley.

PA and BAA feeding stunt alfalfa growth by removing plant juices and producing great amounts of honeydew with the associated sooty mold that contaminate the crop. SAA feeding can kill alfalfa plants by injecting toxins. Once temperatures exceed 800F, PA and BAA populations tend to subside. CA appears to be more heat tolerant than either PA or BAA and thrives in the warmer desert climates of southern California.

Beneficial insects are an important component in aphid management in alfalfa hay. In addition, alfalfa hay serves as a reservoir for beneficial insects for surrounding crops. Common aphid predators include lady beetles, lacewings, syphrid flies, bigeyed bugs and damsel bugs. In addition, a number of wasp species play an important role as aphid management. However, when insecticides are applied for weevil control in early spring the beneficial insect complex can be largely eliminated. Without the effects of the beneficial insects, aphid populations increase and can rapidly reach damaging levels causing considerable damage. Aphid and aphid predator/parasite population monitoring is key to making an appropriate treatment decision. When treatments are warranted, the insecticides used for control of the aphid control include: Lorsban or dimethoate (Dimethoate).

Current Pest Management Program

Central Valley Region

Alfalfa hay is grown on over 600,000 acres of the Central Valley region incorporating Butte, Colusa, Glenn, Placer, Sacramento, Solano, Sutter, Tehama, Yolo, Yuba, Merced, San Joaquin, Stanisalus, Fresno, Kern, Kings, Madera and Tulare counties. While the insect pests species that effect alfalfa production are fairly consistent within the Central Valley, the timing and severity of infestation vary within the region. The longer growing season in the southern portion of the Central Valley allows for more insect pest generations per year. These factors contribute to some of the differences in insecticide use patterns. Within the Central Valley, insecticide usage increases from about one application per acre in the Sacramento Valley compared to about two applications per acre in the southern San Joaquin Valley.

In 1999 the principle organophosphate (OP) insecticide used on alfalfa hay was Lorsban, which was applied to about half of the acreage (Table1). Lorsban was used to control the weevils and aphids. Lorsban was also applied on occasional pests such as leafhoppers. Weevils (especially EAW) are the most significant pests of alfalfa in the Central Valley. Annual control of the weevil complex is required on most alfalfa hay fields. Furadan was used for weevil control on nearly 15% of the acres while Imidan was used for weevil control on over 7% of the total alfalfa growing acres in the Central Valley. When Imidan, Furadan and Lorsban cannot be sprayed because the fields are adjacent to sensitive areas, Malathion can be used for weevil and aphid control. Malathion was applied to about 8% of the alfalfa hay. However, Malathion is not as efficaous as Imidan, Furadan or Lorsban. The pyrethroid insecticides (Warrior, Pounce and Baythroid) were used on 27.6, 6.5% and 5.7% of the acres, respectively. A portion of this usage was also for weevil control.

Aphids are usually held under adequate control by the combined action of beneficial insects and resistant alfalfa varieties. In general, the Central Valley does not require extensive aphid management. However, because insecticide applications for weevil control often eliminate the beneficial insect complex, economically damaging aphid populations can often result. If economically damaging populations are found, then insecticide applications are required to suppress the population. Control of aphids has relied on Lorsban and Dimethoate for aphid control. Lorsban was applied to about 53.1% of the acreage and Dimethoate was applied to 4.4% of the alfalfa growing acres in the Central Valley. In addition to Lorsban and Dimethoate, Furadan as well as Lannate provides short-term aphid control.

Several lepidopterous larval pests may occasionally affect alfalfa fields. AC can be controlled with Bt. Bt was applied to over 3% of the growing acres in this region. Bt is not toxic to beneficial insects and use will not cause aphid or other lepidopterous larval population increases. However, Bt is not effective against the WYA or BAW. Control of the armyworms relies on Lannate, Warrior, Pounce and Baythroid. Lannate was applied to over 13.2% of the alfalfa grown in the Central Valley while Warrior, Pounce and Baythroid were used on 27.6, 6.5% and 5.7% of the acres, respectively.

Desert Region

Alfalfa hay is grown on over 250,000 acres of the desert region incorporating across Imperial, Inyo, Riverside and San Bernardino counties. Imperial County has the largest alfalfa acreage of any county. The insecticide use reflects the long production season, hotter temperatures and the associated importance of aphids and lepidopterous larvae as alfalfa pests.

In 1999 about 50% of the treatments in the desert region were OP insecticides (Table 2). The majority of these applications were directed against the EAW and aphid complex. Weevil activity is usually limited to the first few months of the year (January through March), however managing them is a key element of any pest control program in alfalfa. Malathion was used for both weevil and aphid control and was applied to over 50% of the alfalfa growing acres. Furadan is used for weevil and aphid control and was applied to 22% of the desert alfalfa growing acres. Lorsban, which was used extensively throughout the Central Valley, was applied to less than 19% of the desert alfalfa growing acreage.

Unfortunately, early season treatment for weevils often results in the disruption to natural enemy complexes that help control aphids. This may result in aphid outbreaks, which require further insecticide applications. Dimethoate was applied at least once to all alfalfa grown in the desert region for aphid control. This reflects the importance of aphids and is underscored by the recent increases in CA populations throughout the desert region.

Lepidopterous pests tend to occur throughout the desert region. Of particular concern for the desert region is AC. AC is favored by warm, dry climates the desert region. Control of lepidopterous pests often relies on preserving and encouraging their natural enemies. The most important natural enemies are several parasitic wasps. Desert alfalfa fields should be monitored for AC on a weekly basis throughout the summer months. Since parasitism is critical to containing AC below an economically injurious level, insecticides should be applied only when sweep samples produce an average of 10 nonparasitized caterpillars per sweep. Even then, chemical control is often needed to prevent economic damage. In 1999, over 15% of region was treated with Bt. Armyworms can be important pests in desert region and should be monitored along the same lines as for the AC. Lannate was used for armyworm control and was applied to over 13% of the alfalfa growing acres. Warrior, Baythriod and Pounce were also used for BAW as well as weevil control and was applied to about 22%, 45% and 23% of the alfalfa growing acres in the desert region, respectively.

OP Free – Pest Management Program with Available Technology

The OP free programs below were constructed with currently registered insecticides for immediate implementation and without regard to resistance management consequences. A pest management program in alfalfa, without OP insecticides, would rely on pyrethroid (Pounce, Baythroid and others) and carbamate (Furadan and Lannate) insecticides and Bt (Tables 3 and 4). The weevil complex would be effectively managed using carbamates and pyrethroids. It is anticipated that one application of Baythroid, Warrior or Furadan would be applied for control of low to moderate weevil populations while two applications would be necessary for high, persistent weevil populations. The increased use of carbamate and pyrethroid insecticides would have significant negative impact on natural enemy populations. With elimination of beneficial insects through the use of pyrethroid and carbamate insecticides and without effective aphicides, e.g. dimethoate and Lorsban, control of aphids could be very difficult, particularly in the lower desert region. Aphids are more of a problem in the lower desert region than in the Central Valley. Furadan has activity on aphids, as well as Lannate; both insecticides provide short-term aphid control. However, aphid populations are expected to rapidly rebound after treatment with either of these insecticides. Aphid population outbreaks has been observed in other cropping systems that use the pyrethroid, Pounce. Thus without highly effective aphicides the use of Pounce would be largely curtailed. However, Baythroid and Warrior may provide suppression of moderate to low aphid population. The lepidopterous larvae complex would be effectively managed using Bt and Lannate, as well as with pyrethroid insecticides. Bt products have an inherent weakness on BAW, which is a major alfalfa pest in many areas. Lannate has been used for several years on lepidopterous larvae particularly BAW. With increased use of Lannate for aphids and lepidopterous larvae, resistance of BAW to Lannate is expected to occur within a short period of time. There are some indications that BAW resistance to Lannate has begun to occur in the Central Valley. Other "minor" alfalfa insect pest, e. g., cutworm, leafhoppers and treehoppers, etc, would be controlled with insecticides directed against the major pests. It is anticipated that there would be no significant yield loss over current levels with the loss of OP insecticides.

OP Free – Pest Management Program with Emerging Technology

The IPM programs below were constructed with currently registered insecticides and/or insecticides that are anticipated to be registered within four to five years. The IPM program with emerging technology would produce a stable long-term program that would allow for much greater impact of beneficial insects and mites on the pest populations. The pest management program would maintain low pest densities over time and prevent large pest density oscillations.

New reduced risk products that are expected to be registered within the next few years include imidacloprid (Provado), thiomethoxam (Actara), indoxacarb (Avaunt), spinosad (Success) and methoxyfenozide (Intrepid). Avaunt effectively controls the weevil complex at fairly low rates of application and also provides lepidopterous larval control, albeit at higher rates. Avaunt has only a moderate detrimental effect on natural enemies and thus would not cause secondary outbreaks of the aphid species complex or lepidopteran larval species complex. It is anticipated that one or two applications of Avaunt would be needed to suppress the weevil complex (Tables 5 and 6). Since Avaunt would not eliminate the beneficial insects that attack the aphid, aphids would not increase to the levels observed when carbamate or pyrethroid insecticides are used for weevil complex control. If aphids do become a problem, then two neonicotinoid insects, Provado and Actara, are very effective aphicides at very low rates of application. It is anticipated that one or two applications of Provado or Actara would be needed to suppress the aphid species complex. Again these neonicotinoid insecticides have only moderate detrimental effect on natural enemies and thus would not cause secondary outbreaks of the lepidopteran larval species complex. However, if lepidopterous larvae become a problem, then Success and Intrepid have very good activity on lepidopterous larvae, particularly against the armyworms. These two reduced risk insecticides have little toxicity to beneficial insects. Intrepid is an insect growth regulator that is specific to lepidopterous larvae and has no known toxicity of beneficial insects while Success is a secondary metabolite of actinomycete, Saccharopolyspora spinosa, and has limited toxicity to beneficial insects. Success does have known toxicity to honeybees and it is speculated that Success may suppress beneficial hymenoptera to some extent. Finally, because of cost considerations, Bt would still be used to some extent for control of AC. However, the amount of Bt used would likely be reduced because of the efficacy of Success and Intrepid.

The future of insect pest management for alfalfa is very promising with the expected registration of new reduced risk insecticides. These insecticides would allow for better utilization of existing biological control of aphid and lepidopterous larval pests and produce a stable long-term pest management system. The key to the development of this system is control of the weevil complex with environmental benign insecticides like Avaunt. However, in the short term, insect pest management of alfalfa without OP insecticides would be very difficult and costly.

Table 1. Insecticide and Miticide Use on Alfalfa in the Central Valley Region of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
Bacillus thuringeinesis (Various Products)	494	17,605	3.4	$15,256
carbofuran (Furadan)	32,574	75,481	14.7	$686,650
chlorpyrifos (Lorsban)	153,962	273,266	53.1	$2,912,962
cyfluthrin (Baythroid)	1,046	29,494	5.7	$303,384
dimethoate (Dimethoate)	8,444	22,659	4.4	$83,177
lambda-cyhalothrin (Warrior)	3,852	142,274	27.6	$1,617,907
malathion (Malathion)	51,681	40,067	7.8	$282,693
methomyl (Lannate)	44,418	75,886	14.7	$986,963
permethrin (Pounce, Ambush)	4,088	33,452	6.5	$275,965
phosmet (Imidan)	25,695	37,615	7.3	$266,198

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the Central Valley Region is about $14.43.

Table 2. Insecticide and Miticide Use on Alfalfa in the Desert Region of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
Bacillus thuringeinesis (Various Products)	2,338	47,262	15.4	$72,187
carbofuran (Furadan)	28,622	68,206	22.2	$603,355
chlorpyrifos (Lorsban)	33,891	57,242	18.7	$641,216
cyfluthrin (Baythroid)	4,335	137,805	44.9	$1,257,054
dimethoate (Dimethoate)	128,845	334,565	109.1	$1,269,126
lambda-cyhalothrin (Warrior)	1,608	66,323	21.6	$675,570
malathion (Malathion)	186,900	158,989	51.8	$1,022,342
methomyl (Lannate)	25,827	42,436	13.8	$573,883
permethrin (Pounce, Ambush)	8,032	70,786	23.1	$542,149
phosmet (Imidan	450	686	0.2	$4,662

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the Desert Region is about $21.72.

Table 3. Insecticide and Miticide Use in an OP free IPM System with Available Technology on Alfalfa in the Lower Desert and Central Valley under Moderate Insect Population Pressure.

Material	**Rate Form/ac**	**# Appl./ Season**	**Pest**	**Notes**
cyfluthrin (Baythroid 2)	1/8 pt	1	Weevils	destroys natural enemies, suppresses moderate aphid populations but aphids may rebound
or				
lambda-cyhalothrin (Warrior T)	1/5 pt			
or				
permethrin (Pounce 3.2EC)	1/4 pt			
carbofuran (Furadan 4F)	1 pt	1	Weevils	same as Baythriod and aphids
methomyl (Lannate SP)	1 lb	1	Lepidopterous larvae and aphids	same as Baytriod
Bacillus thuringiensis (Dipel DF and others)	1 lb	1/2	Lepidopterous larvae	weak on BAW

Table 4. Insecticide and Miticide Use in an OP free IPM System with Available Technology on Alfalfa in the Lower Desert and Central Valley under High Insect Population Pressure

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
cyfluthrin (Baythroid 2) or lambda cyhalothrin (Warrior T) or	1/8 pt	2	Weevils	destroys natural enemies, suppresses moderate aphid populations but aphids may rebound
permethrin (Pounce 3.2EC)	1/4 pt			
carbofuran (Furadan 4F)	1 pt	2	Weevils and aphids	same as Baythroid
methomyl (Lannate SP)	1 lb	2	Lepidopterous larvae and aphids	same as Baythroid
Bacillus thuringiensis (Dipel DF and others)	1 lb	1/2	Lepidopterous Larvae	weak on BAW

Table 5. Insecticide and Miticide Use in an OP free IPM System with Emerging Technology on Alfalfa in the Lower Desert and Central Valley under Moderate Insect Population Pressure

Material	**Rate Form/ac**	**# Appl./ Season**	**Pest**	**Notes**
indoxacarb (Avaunt 30WG)	3/8 pt	1	Weevils and lepidopterous larvae	
imidacloprid (Provado 1.6F)	1/4 pt	1/2	aphids	
or				
thiomethoxam (Actara 25WG)	0.2 lb			
spinosad (Success 2SC)	1/2 pt	1	Lepidopterous larvae	
or				
methoxyfenozide (Intrepid 2F)	1 pt			
Bacillus thuringiensis (Dipel DF and others)	1 lb	1/8	Lepidopterous larvae	weak on BAW

Table 6. Insecticide and Miticide Use in an OP free IPM System with Emerging Technology on Alfalfa in the Lower Desert and Central Valley under High Insect Population Pressure

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
indoxacarb (Avaunt 30WG)	3/8 pt	2	Weevils and lepidopterous larave	
imidacloprid (Provado 1.6F)	1/4 pt	2	aphids	
or				
thiomethoxam (Actara 25WG)	0.2 lb			
spinosad (Success 2SC)	1/2 pt	1	Lepidopterous larvae	
or				
methoxyfenozide (Intrepid 2F)	1 pt			
Bacillus thuringiensis (Dipel DF and others)	1 lb	1/4	Lepidopterous larvae	weak on BAW

ALMONDS

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California is the only state in the United States to commercially produce almonds and over 99% of California's almonds are grown in the San Joaquin and Sacramento valleys. In the San Joaquin Valley about 80% of California's production occurs in Kern and Fresno counties in the south and Merced and Stanislaus counties in the north. Glenn, Butte and Colusa counties in the northern Sacramento Valley account for approximately 15% of the annual production. Furthermore, California produces about 75% of the world's almond production.

There are over 50 almond varieties that are grown commercially in California with Nonpareil being the predominate variety. A large number of insect and mite pests attack almonds in California. These pests are present in all almond growing areas of the state and can occur at damaging levels during most seasons. The most significant insect pests of almonds include peach twig borer (PTB), navel orangeworm (NOW), San Jose scale (SJS), ants and mites. However, once sporadic or previously insignificant insect pests are now emerging as potentially destructive species. These include pests such as the obliquebanded leafroller (OBLR) and the European fruit lecanium. The emergence of "new pests" has resulted largely due to the elimination of dormant/delayed dormant applications and will require further attention as limits are placed on control options.

Navel Orangeworm, *Amyelois transitella*

Navel orangeworm is the most important insect pest of almonds in California. NOW overwinter as larvae inside unharvested "mummy" nuts left on the tree and in trash nuts left on the ground. Moths of the overwintering brood emerge in spring and lay eggs on mummy nuts or nuts damaged by PTB. NOW cannot infest sound nuts until hull split. Thus, PTB damaged nuts act as a food bridge for the overwintering NOW generation. The reliance of NOW on PTB damaged nuts make PTB control extremely important. NOW larvae mature inside nuts, producing large amounts of frass and webbing rendering nuts unmarketable. After hull split, adults lay eggs directly on the hull of sound nuts and the tiny larvae enter nuts through the shell seal. NOW produce three to four generations per year with as much as 30% damage occurring in late harvested orchards. NOW attacks most soft-shell cultivars or cultivars with a poor nut seal. Hard shell nut cultivars are less susceptible to attack. Control of NOW relies on orchard sanitation (removal and destruction of mummy nuts), prompt or early harvest, on-farm fumigation and chemical control. Pre-harvest insecticide applications are an important component of a NOW control program and can provide about 50% control. However, the most effective way to prevent economically damaging populations of NOW is the removal and destruction of mummy nuts by February and prompt harvest after hull split.

Orchard sanitation and prompt harvest after hull split can prevent NOW damage without the use of broad-spectrum insecticide. If orchard sanitation is not practiced or the crop cannot be harvested promptly after hull split, then broad-spectrum insecticides may be required for NOW control. However, broad-spectrum insecticides provide only marginal control. One of the most effective broad-spectrum insecticides is azinphos-methyl (Guthion). Guthion is somewhat selective for predaceous mites, but highly toxic to parasitic wasps and generalist predators. Guthion provides longer residual and is less disruptive to natural enemies compared to the alternatives, permethrin (Pounce) and esfenvalerate (Asana). phosmet (Imidan), carbaryl (Sevin) and chlorpyrifos (Lorsban) may serve as alternatives to Guthion and will reduce NOW populations if used during the in-season, but may contribute to spider mite outbreaks. Also all of these broad-spectrum insecticides eliminate two parasitic wasps, *Pentalitomastix plethorica* and *Goniozus legneri*, that help suppress the NOW population.

Peach Twig Borer, *Anarsia lineatela*

Peach twig borer is a major pest in almonds and may also contribute to NOW problems. Prior to the establishment of NOW into California in the 1940's, PTB was the most important lepidopterous pest of almonds. In the absence of adequate control measures, the potential for extensive losses to PTB still exists. PTB often damage almonds by feeding in rapidly growing shoots that can make it difficult to train young trees. However, direct feeding on nutmeat causes the greatest economic damage. Soft-shell almonds are most susceptible to damage from PTB. Before current insecticides were available, the California Almond Growers Exchange recorded damage as high as 71%. Even now, in soft-shell varieties, it is not uncommon to experience greater than 30% nut damage in untreated orchards. When PTB larvae have completed their development, the larvae leave nuts by making an exit hole that can serve as an entry site for NOW. Populations of PTB are present in most California orchards and usually require some control activity.

Control of PTB has traditionally relied on dormant/delayed dormant applications of horticultural oil combined with an insecticide and/or an insecticide application during the in-season. Dormant/delayed dormant applications usually include horticultural oil combined with spinosad (Success), diazinon (Diazinon), Pounce, Asana, Lorsban, Imidan or methidathion (Supracide). Supracide can be used without horticultural oil. Control during the in-season has relied on *Bacillus thuringiensis* (Bt) at bloom and/or post-bloom, and either Success, Lorsban, Imidan, Guthion, Supracide or Asana in May. Success is a newly registered reduced risk insecticide that is very effective against PTB. Success is as effective as organophosphate (OP) insecticides. Diazinon is extensively used during dormant/delayed dormant period for control of PTB, SJS, European red and brown almond mite eggs and fruittree leafroller eggs. However, PTB and SJS have exhibited some level of resistance to Diazinon in the San Joaquin Valley. Asana and Pounce are highly effective for PTB control when applied during the dormant/delayed dormant period. Asana and Pounce are also effective against NOW and other lepidopterous pests if used during the in-season. Asana has low mammalian toxicity and is an economical alternative to OP insecticides. However, these materials are very disruptive to the biological control of mites and should only be used during the in-season in an emergency situation. Resistance to Asana has also developed in some growing areas

PTB can be controlled during bloom with well-timed treatments of Bt. In most orchards, this spray can provide satisfactory control without further applications during the in-season. Bt is applied at the beginning and late bloom during warm spring weather. Warm weather is essential since PTB does considerable feeding on leaves and stems during bloom before boring into new shoots. If PTB is actively feeding then they can ingest lethal amounts of Bt at this time. Bt is often not effective during cold, wet springs. Mating disruption has been used for PTB on almonds although it is usually utilized in higher value, more labor-intensive crops such as peaches. Results have been variable and the cost of this program is currently too high for it to be widely adopted in almonds at this time.

San Jose Scale, *Quadraspidiotus perniciosus*

While San Jose scale is not the major concern of almond growers in the state, severe infestations will kill fruit wood and reduce production by as much as 10%. Severe infestation over a number of years may eventually kill almond trees. SJS has three to five generations per year depending on the growing region. SJS suck plant juices from the inner bark of twigs and branches. Infested branches may stop growing and heavily infested branches and spurs will die. Control of SJS should be applied during the dormant/delayed dormant period and/or in early season after egg hatch. High rates of dormant oils applied during the early part of the dormant period is effective in controlling SJS populations when no broad-spectrum insecticides are used within the in-season. The applications of broad-spectrum insecticides during the in-season eliminate most beneficial insects that maintain low SJS populations. In most cases, OP insecticides are not needed for control of this pest.

Mite complex:

Twospotted Spider Mite (TSSM), *Tetranychus urticae*
Pacific Spider Mite (PSM), *Tetranychus pacificus*
European Red Mite (ERM), *Panonychus ulmi*
Brown Almond Mite (BAM), *Bryobia rubrioculus*

Twospotted spider mite and Pacific spider mite can cause significant damage to almonds. Large populations can cause complete defoliation of the trees that will result in sunburned fruit, reduced fruit size and excess foliage on the orchard floor that interferes with harvest. Severe defoliation early in the season can cause a 25% reduction in yield the following year. The potential for direct damage decreases as the season progresses. PSM and TSSM overwinter as adult females in the trees or on the orchard floor. As the weather warms in the spring, PSM and TSSM increase in numbers and move throughout the tree. Both species favor hot, dry conditions and can develop damaging populations in early summer. PSM is the dominant species in the southern San Joaquin Valley with the TSSM predominating in the Sacramento and northern San Joaquin Valley.

Brown almond mite and European red mite can build up to high numbers but seldom reach damaging populations. They can serve as a stable food source for TSSM and PSM predators. ERM and BAM overwinter as eggs under bark and at the base of buds. These mites usually affect leaves by causing mottling and bronzing, though leaf drop is uncommon. Dormant sprays along with beneficial insects and mites keep populations below an economically damaging level. Predaceous mites, primarily the western predatory mite, *Galandromus occidentalis*, seems to be somewhat resistant to OP and insect growth regulator (IGR) insecticides. However, they are extremely susceptible to pyrethroid and carbamate insecticides. The use of pyrethroid and carbamate insecticides during the in-season can contribute to severe mite flare-ups. Other important predators include six-spotted thrips, *Scolothrips sexmaculatus*, the minute pirate bug, *Orius tristicolor*, and the spider mite destroyer, *Stethorus picipes*. Chemical control of mites usually consists of a propargite (Omite) application during the in-season. Omite is the most effective miticide now available that does not severely disrupt biological control of mites. Fenbutatin-oxide (Vendex) is also effective but works poorly in cooler temperatures and wet climates. Vendex has little effect on mite predators.

Ants Complex:

Pavement Ant, *Tetrameorium caespitum*
Southern Fire Ant, *Solenopsis xyloni*

Ants are significant pests of almonds, particularly in the central and southern regions of the San Joaquin Valley. As the use of drip irrigation and mini-sprinklers increases, ants could possibly increase in importance in other areas. Ants are principally a problem after almond harvest when the nuts are on the ground. Ant damage increases in relation to the length of time they remain on the ground before being picked up. Ants can completely hollow out nutmeat leaving only the pellicle. Damage is lower on varieties with good shell seals, but can exceed 20% in susceptible soft-shell cultivars. Currently, the most effective registered materials for control of ants are Lorsban, pyriproxyfen (Distance) and abermectin (Clinch) bait.

Current Pest Management Program

Southern San Joaquin Valley

The southern San Joaquin Valley consists of Fresno, Kern, Kings, Madera and Tulare counties and has about 229,000 bearing acres of almonds with the majority of the acreage in Fresno and Kern counties. Orchards typically receive a dormant/delayed dormant application of horticultural oil combined with an insecticide. Growers prefer the use in-season use of OP insecticides instead of pyrethroid insecticides because of the concern of mite problems. In 1999, nearly all orchards received a dormant/delayed dormant application of horticultural oil for control of PTB, SJS, ERM, BAM and OBLR (Table 1). The horticultural oil was combined with a pyrethroid on about 40% of the acres and with an OP insecticide or Success on about 50% of the acres. The most common OP insecticides used during the dormant/delayed dormant application are Lorsban and Diazinon. Supracide is used also during the dormant/delayed dormant application without horticultural oil particularly when SJS is a problem.

In addition to the dormant/delayed dormant applications, about 30% of the acres were treated with Bt during bloom for PTB control. The Bt bloom applications can serve as an alternative to dormant/delayed dormant applications for control of PTB. In addition to the bloom applications, about 15% of the acres were treated with Success. Success was applied at post bloom or during the May application timing for PTB control. Success should not be applied during bloom because of honeybee mortality. The May application timing is also used for NOW control along with hull split application timing. Guthion was applied to about 18% of the acres and Imidan about 18% of the acres. Guthion and Imidan are used mainly for NOW control at the May or hull split timings.

Spider mites are a significant pest in the southern San Joaquin Valley and it is often necessary to apply a miticide. In 1999, over 60% of the acres were treated with a miticide and Omite was applied to over 50% of the acres. In addition to Omite, abermectin (Agri-Mek) was applied to 26% of the acres. However, Clinch, which is also abermectin, was also used for ant control as a bait formulation. Ants are a very serious problem in the southern San Joaquin Valley. Besides Clinch and Distance, which is a recently registered reduced risk insecticide, Lorsban bait also serves as a key insecticide for ant control.

Northern San Joaquin Valley

The northern San Joaquin Valley consists of Merced, San Joaquin and Stanislaus counties and has about 203,000 bearing acres of almonds. About 70% of the northern San Joaquin Valley almonds receive a dormant/delayed dormant horticultural oil application with the majority of applications combined with an insecticide (Table 2). The insecticide used in combination with the dormant/delayed dormant application were Asana, Pounce, Lorsban or Diazinon. Supracide is also used during the dormant/delayed dormant application without horticultural oil particularly when SJS is a problem. In addition to the dormant/delayed dormant applications, about 15% of the acres were treated with Bt during bloom for PTB control. The Bt bloom applications serve as an alternative to dormant/delayed dormant applications for control of PTB. In addition to the dormant/delayed dormant and bloom applications, a low percent of the acres are treated at hull split for NOW and PTB. Hull split application usually consists of Asana, Pounce, Guthion or Imidan. The percent of acres treated with an OP insecticide in northern San Joaquin Valley was only about 50% while in the southern San Joaquin Valley nearly 100% of the acres were treated with an OP insecticide. However, about 50% of the areas in northern San Joaquin Valley were treated with a pyrethroid while only 40% of the acres were treated with a pyrethroid in the southern San Joaquin Valley.

Spider mites can be a significant pest in the northern San Joaquin Valley and often require a miticide. However, spider mites are far less of a problem in the northern San Joaquin Valley compared to the southern San Joaquin Valley. In 1999, about 40% of the acres were treated with a miticide, with Omite applied to about 30% of the acres in the northern San Joaquin Valley. In addition to Omite, Agri-Mek was applied to about 14% of the acres.

Ants can be a serious problem in the northern San Joaquin Valley, but not to the extent as they are in southern San Joaquin Valley. Ant control relies on Lorsban and Clinch as a bait formulation.

Sacramento Valley

The Sacramento Valley consists of Butte, Colusa, Glenn, Placer, Sacramento, Solano, Sutter, Tehama, Yolo and Yuba Counties and has about 105,000 bearing acres of almonds. About 50% of the Sacramento Valley almonds receive a dormant/delayed dormant horticultural oil application with the majority of applications combined with an insecticide (Table 3). The insecticide used in combination with the dormant/delayed dormant application were Asana, Pounce, Lorsban or Diazinon. The reduction in the dormant/delayed dormant application combined with an insecticide in the Sacramento Valley and northern San Joaquin Valley compared to the southern San Joaquin Valley is the result of growers' concerns with pesticides found in the Sacramento and San Joaquin rivers following winter and late spring rains and the difficulty of applying a dormant/delayed dormant application following rain in the northern portion of the state. Because growers have reduced the dormant/delayed dormant applications, about 20% of the acres were treated with Bt during bloom for PTB control. The Bt bloom applications serve as an alternative to dormant/delayed dormant applications for control of PTB. In addition to the bloom applications, about 6% of the acres were treated with Success. Success was applied during the May application timing for PTB control. Success should not be applied during bloom because of honeybee mortality. The May application timing is also used for NOW control along with hull split application timing. Hull split application usually consists of Asana, Pounce, Guthion and Imidan.

Spider mites are not a major concern in the Sacramento Valley and often miticides are not required. In 1999, about 25% of the acres were treated with a miticide, with Omite applied to about 19% of the acres in the Sacramento Valley. In addition to Omite, Agri-Mek was applied to about 5% of the acres. Ants are not a serious problem in the Sacramento Valley. Ant control relies on Lorsban and Clinch as a bait formulation.

OP Free – Pest Management Program with Available Technology

The OP free programs below were constructed with currently registered insecticides for immediate implementation and without regard to resistance management consequences. The backbone of a pest management program for almonds in all regions would rely on prompt harvest after hull split and winter orchard sanitation to reduce NOW populations. These two cultural practices should reduce the NOW population to very manageable levels. In addition, all orchards would receive a dormant/delayed dormant application of horticultural oil plus pyrethroid insecticide or Success for PTB, ERM, BAM and OBLR control.

Southern San Joaquin Valley

In addition to the above standard control measures, all orchards with large NOW and PTB populations would rely on two applications of Bt at bloom or one application of Success at the May timing for PTB control and a hull split application of a pyrethroid insecticide for NOW (Table 4). The Success application may be applied at post-bloom if OBLR is more of a significant problem than PTB. Success is very effective against both OBLR and PTB. However, Success should not be applied during bloom because of honeybee toxicity. This program should prevent any damage in excess of current levels. However, the dormant/delayed dormant and in-season applications of pyrethroid insecticides will suppress the beneficial insect and mite complex that helps maintain TSSM, PSM and SJS populations. With reduced levels of beneficial insects and mites, TSSM and PSM would require about two miticide applications. However, it should be noted that because of the hot dry climate of the southern San Joaquin Valley, TSSM and PSM populations often require an application of a miticide even in the absence of insecticides. This pest management system would be very unstable and would lead to the rapid development of TSSM and PSM resistance to all available miticides. A number of new miticides (milbemectin and spirodicolfen) are currently in development. Their registration is expected in the near future. Also, the miticidal pyrethroids [fenpropathrin (Danitol) and bifenthrin (Brigade)] that are near registration would be only effective as miticides for a short period of time because of the rapid development of resistance by the mites. Danitol and Brigade would provide control of NOW and would replace the older pyrethroids, i.e. Asana and Pounce.

In addition, the predators and parasites of SJS would be largely depleted by the applications of pyrethroid insecticides. Pyrethroid insecticides are not highly effective for scale control. Increased scale populations would require an application of pyriproxyfen (Esteem) to about half of the acreage. At harvest, almonds are shook from the trees and dried on the orchard floor before being removed from the orchards. Ants can cause significant damage during the time that the nuts are on the ground. Ants are more of a problem in the southern San Joaquin Valley than in other areas of the state. However, significant ant damage can occur in all almond growing regions. Control of ants would rely on Distance or Clinch bait. Distance or Clinch would be applied to about three fourths of the acreage.

In orchards with low PTB and NOW populations, control would rely less on pyrethroid insecticides and more on Bt and Success (Table 5). In addition to the prompt harvest, winter orchard sanitation to reduce NOW and a dormant/delayed dormant application of horticultural oil plus pyrethroid insecticide or Success for PTB, ERM, BAM and OBLR control, all orchards would rely on two applications of Bt at bloom or one application of Success at the May timing for PTB control. The Success application may be applied at post-bloom if OBLR is more of a significant problem than PTB. This program should prevent any damage in excess of current levels. Without in-season and possibly dormant/delayed dormant applications of pyrethroid insecticides, the parasitoids of NOW (*Pentalitomastix plethorica* and *Goniozus legneri*) would aid in the control of NOW and beneficial insect and mite complex would suppress the TSSM and PSM populations. However, as noted earlier, the hot dry climate of the southern San Joaquin Valley often require an application of a miticide for TSSM and PSM control even in the absence of pyrethroid insecticides. With beneficial insects and mites aiding in control, management of TSSM and PSM would require a miticide application to about one third of the acreage. Also without in-season and possibly dormant/delayed dormant applications of pyrethroid insecticide, the predators and parasites of SJS will not be depleted and would suppress the SJS populations. SJS populations would require an application of Esteem to about one third of the acreage. Ants are not suppressed by beneficial insects and the removal of the in-season pyrethroids insecticides may even enhance the ant problem since the in-season pyrethroid applications suppress to some extent the ant populations. Control of ants would rely on a single bait application of Distance or Clinch.

Northern San Joaquin Valley

In addition to the prompt harvest, winter orchard sanitation to reduce NOW and a dormant/delayed dormant application of horticultural oil plus pyrethroid insecticide or Success for PTB, ERM, BAM and OBLR control, additional control in orchards with high PTB and NOW populations would rely on two applications of Bt at bloom or one application of Success at the May timing for PTB control and a hull split application of a pyrethroid insecticide for NOW

(Table 6). The Success application may be applied at post-bloom if OBLR is more of a significant problem than PTB. This program should prevent any damage in excess of current levels. The dormant/delayed dormant and in-season applications of pyrethroid insecticides will suppress the beneficial insect and mite complex that helps maintain TSSM, PSM and SJS populations in the same manner as in the southern San Joaquin Valley. However, TSSM and PSM are not as significant a problem in the northern San Joaquin Valley as in the southern San Joaquin Valley. In general, Sacramento Valley has less TSSM and PSM than northern San Joaquin, which has less TSSM and PSM than the southern San Joaquin Valley. It appears that the higher humidity and slightly cooler temperatures in northern San Joaquin and Sacramento valleys suppress spider mite populations compared to southern San Joaquin Valley and growers in the northern San Joaquin Valley would need to apply only one miticide application for TSSM and PSM control. In addition, the predators and parasites of SJS would be largely depleted by the applications of pyrethroid insecticides. Increased scale populations would require an application of Esteem to about half of the acreage. Ants can cause significant damage to almonds in the northern San Joaquin Valley. However, ants are more of a problem in the southern San Joaquin Valley than in northern San Joaquin or Sacramento valleys. Control of ants would rely on Distance or Clinch bait. Distance or Clinch would be applied to about half of the acreage.

In orchards with low PTB and NOW populations control would rely on a dormant/delayed dormant application of Success combined with horticultural oil and in-season applications of Bt for PTB (Table 7). NOW control would rely on prompt harvest and winter orchard sanitation. Since pyrethroid insecticides would not be applied in-season, the parasitoids of NOW (*Pentalitomastix plethorica* and *Goniozus legneri*) would aid in the control of NOW and the beneficial insect and mite complex would suppress the TSSM and PSM populations. With beneficial insects aiding in control, management of TSSM and PSM would require a miticide application on half of the acreage. Also without an in-season application of a pyrethroid insecticide, the predators and parasites of SJS will not be depleted and would suppress the SJS populations. SJS populations would require an application of Esteem to about one third of the acreage. Ants are not suppressed by beneficial insects and the removal of the in-season pyrethroids insecticides may even enhance ant problems since the in-season pyrethroid applications suppress to some extent the ant populations. Control of ants would rely on Distance or Clinch bait. Distance or Clinch would be applied to about half of the acreage.

Sacramento Valleys

In addition to the prompt harvest, winter orchard sanitation to reduce NOW and a dormant/delayed dormant application of horticultural oil plus pyrethroid insecticide or Success for PTB, ERM, BAM and OBLR control, additional control in orchards with high PTB and NOW populations would rely on two applications of Bt at bloom or one application of Success at the May timing for PTB control (Table 8). This program should prevent any damage in excess of current levels. Since pyrethroid insecticides would not be applied in-season, the parasitoids of NOW (*Pentalitomastix plethorica* and *Goniozus legneri*) would aid in the control of NOW and the beneficial insect and mite complex would suppress the TSSM and PSM populations. With beneficial insects and mites aiding in control, management of TSSM and PSM would require a miticide application on about half of the acreage. Also without in-season applications of a pyrethroid insecticide, the predators and parasites of SJS will not be depleted and would suppress the SJS populations. SJS populations would require an application of Esteem to about one third of the acreage. Ants are not suppressed by beneficial insects and the removal of the in-season pyrethroids insecticides may even enhance ant problems since the in-season pyrethroid applications suppress to some extent the ant populations. Control of ants would rely on Distance or Clinch bait. Distance or Clinch would be applied to about quarter of the acreage.

In orchards with low PTB and NOW populations, control would rely on a dormant/delayed dormant application of Success combined with horticultural oil and in-season applications of Bt for PTB (Table 9). NOW control would rely on prompt harvest and winter orchard sanitation. Since pyrethroid insecticides would not be applied, the parasitoids of NOW (*Pentalitomastix plethorica* and *Goniozus legneri*) would aid in the control of NOW and beneficial insect and mite complex would suppress the TSSM and PSM populations. With the beneficial insects aiding in control, management of TSSM and PSM would require a miticide application to about an eighth of the acreage. Also without in-season or dormant/delayed dormant applications of pyrethroid insecticide, the predators and parasites of SJS will not be depleted and would suppress the SJS populations. SJS populations would require an application of Esteem on about a quarter of the acreage. Ants are not suppressed by beneficial insects and the removal of the in-season pyrethroid insecticides may even enhance ant problems since the in-season pyrethroid applications suppress to some extent the ant populations. Control of ants would rely on Distance or Clinch bait. Distance or Clinch would be applied to about half of the acreage.

OP Free – Pest Management Program with Emerging Technology

The pest managment programs below were constructed with currently registered insecticides and/or insecticides or control methods that are anticipated to be registered within four to five years. The pest management program with emerging technology would produce a stable long-term program that would allow for much greater impact of beneficial insects and mites on the pest populations. The pest management program would maintain low densities over time and prevent large pest density oscillations. The backbone of a pest management program for almonds in all regions would rely on prompt harvest after hull split and winter orchard sanitation to reduce NOW populations. These two cultural practices should reduce the NOW population to very manageable levels. In addition, all orchards would receive a dormant/delayed dormant application of horticultural oil plus Success for PTB, ERM. BAM and OBLR control.

Southern San Joaquin Valley

In addition to the above standard control measures, all orchards with large NOW and PTB populations would rely on two applications of Bt at bloom or one application of Success at post-bloom for PTB control and two applications of a neonicotinoid insecticide at May and hull split timings for NOW (Table 10). The neonicotinoid insecticides, acetamiprid (Assail) and thiacloprid (Calypso) have shown to provide effective control of cryptic lepidopterous pests and would be applied at both May and hull split timings. Since a neonicotinoid insecticide will be applied at the May timing, Success would be applied at post-bloom. Assail and Calypso applied at the May timing would provide additional PTB control. This program should prevent any damage in excess of current levels.

Since pyrethroid insecticides would not be applied in-season or during the dormant/delayed dormant period and since Assail or Calypso are reduced risk insecticides that are not highly toxic to the beneficial insect and mite complex, management of TSSM and PSM would require only one miticide application. Also the parasitoids of NOW (*Pentalitomastix plethorica* and *Goniozus legneri*) would aid in the control of NOW. Also without an in-season application of a pyrethroid insecticide, the predators and parasites of SJS will not be depleted and would suppress the SJS populations. SJS populations would require an application of Esteem to about one third of the acreage. Ants are not suppressed by beneficial insects and the removal of the in-season pyrethroids insecticides may even enhance ant problems since the in-season pyrethroid applications suppress to some extent the ant populations. Control of ants would rely on one application of Distance or Clinch bait.

In addition to the standard control procedures, all orchards with low PTB and NOW populations would rely on two applications of Bt at bloom or one application of Success at the May timing for PTB control and one application of a neonicotinoid insecticide at hull split timings for NOW (Table 11). The Success application may be applied at post-bloom if OBLR is more of a significant problem than PTB. This program should prevent any damage in excess of current levels. Without in-season and dormant/delayed dormant applications of pyrethroid insecticides, the parasitoids of NOW (*Pentalitomastix plethorica* and *Goniozus legneri*) would aid in the control of NOW and beneficial insect and mite complex would suppress the TSSM and PSM populations. With beneficial insects aiding in control, management of TSSM and PSM would require a miticide application to about three quarters of the acreage. Also without pyrethroid insecticides, the predators and parasites of SJS will not be depleted and would suppress the SJS populations. SJS populations would require an application of Esteem to about one third of the acreage. Ants are not suppressed by beneficial insects and control of ants would rely on a single bait application of Distance or Clinch.

Northern San Joaquin Valley

In addition to the standard control procedures, all orchards with high PTB and NOW populations would rely on two applications of Bt at bloom or one application of Success at the May timing for PTB control and one application of a neonicotinoid insecticide at hull split timings for NOW (Table 12). The Success application may be applied at post-bloom if OBLR is more of a significant problem than PTB. This program should prevent any damage in excess of current levels. Without in-season and dormant/delayed dormant applications of pyrethroid insecticides, the parasitoids of NOW (*Pentalitomastix plethorica* and *Goniozus legneri*) would aid in the control of NOW and beneficial insect and mite complex would suppress the TSSM and PSM populations. With beneficial insects and mites aiding in control, management of TSSM and PSM would require a miticide application to about half of the acreage. Also without pyrethroid insecticides, the predators and parasites of SJS will not be depleted and would suppress the SJS populations. SJS populations would require an application of Esteem to about one third of the acreage. Ants are not suppressed by beneficial insects and control of ants would rely on Distance or Clinch applied to about half of the acreage.

In addition to the standard control procedures, orchards with low PTB and NOW populations would rely on two applications of Bt at bloom that would be applied to about half of the acreage or about half an application of Success at the May timing for PTB control (Table 13). The Success application may be applied at post-bloom if OBLR is more of a significant problem than PTB. This program should prevent any damage in excess of current levels. Without in-season and dormant/delayed dormant applications of pyrethroid insecticides, the parasitoids of NOW (*Pentalitomastix plethorica* and *Goniozus legneri*) would aid in the control of NOW and beneficial insect and mite complex would suppress the TSSM and PSM populations. With beneficial insects and mites aiding in control, management of TSSM and PSM would require a miticide application to about a quarter of the acreage. Also without pyrethroid insecticides, the predators and parasites of SJS will not be depleted and would suppress the SJS populations. SJS populations would require an application of Esteem to about a quarter of the acreage. Ants are not suppressed by beneficial insects and control of ants would rely on Distance or Clinch applied to about half of the acreage.

Sacramento Valley

In addition to the standard control procedures, all orchards with high PTB and NOW populations would rely on two applications of Bt at bloom or one application of Success at the May timing for PTB control and one application of a neonicotinoid insecticide at hull split timings for NOW (Table 14). The Success application may be applied at post-bloom if OBLR is more of a significant problem than PTB. This program should prevent any damage in excess of current levels. Without in-season and dormant/delayed dormant applications of pyrethroid insecticides, the parasitoids of NOW (*Pentalitomastix plethorica* and *Goniozus legneri*) would aid in the control of NOW and beneficial insect and mite complex would suppress the TSSM and PSM populations. With beneficial insects aiding in control, management of TSSM and PSM would require a miticide application to about a quarter of the acreage. Also without pyrethroid insecticides, the predators and parasites of SJS will not be depleted and would suppress the SJS populations. SJS populations would require an application of Esteem to about one third of the acreage. Ants are not suppressed by beneficial insects and control of ants would rely on Distance or Clinch applied to about half of the acreage.

In orchards with low PTB and NOW populations, control would rely on a dormant/delayed dormant application of Success combined with horticultural oil or in-season applications of Bt for PTB (Table 15). NOW control would rely on prompt harvest and winter orchard sanitation. Since neither pyrethroid nor neonicotinoid insecticides would be applied, the parasitoids of NOW (*Pentalitomastix plethorica* and *Goniozus legneri*) would aid in the control of NOW and beneficial insect and mite complex would suppress the TSSM and PSM populations. With the beneficial insects and mites aiding in control, management of TSSM and PSM would require a miticide application to about an eighth of the acreage. Also without in-season or dormant/delayed dormant applications of pyrethroid insecticide, the predators and parasites of SJS will not be depleted and would suppress the SJS populations. SJS populations would require an application of Esteem on about a quarter of the acreage. Ants are not suppressed by beneficial insects and control of ants would rely on Distance or Clinch applied to about half of the acreage.

Addendum

A new miticide, hexythiazox (Savey), has been registered in almond since the economic analysis. Savey will be added to the existing arsenal of miticides, e.g., propargite (Omite), abermectin (Agri-Mek), clofentezine (Apollo) and fenbutatin-oxide (Vendex). Savey will increase the number of available miticides and hopefully reduce miticide costs. However, Savey will not have a major impact on almond IPM.

Table 1. Insecticide and Miticide Use on Almonds in the Southern San Joaquin Valley of CA, 1999

Material*	**Lb (ai)**	**Acres Treated**	**% Acres Treated**	**Costs**
abermectin (Agri-Mek, Clinch)	532	60,162	26.3	$2,663,004
azinphos-methyl (Guthion)	80,114	42,343	18.5	$1,664,764
Bacillus thuringiensis (Various Products)	4,764	62,286	27.3	$147,117
chlorpyrifos (Lorsban)	131,795	77,825	34.1	$2,493,562
clofentezine (Apollo)	1,011	3,386	1.5	$386,347
diazinon (Diazinon)	60,171	29,313	12.8	$555,978
esfenvalerate (Asana)	2,034	48,440	21.2	$369,784
fenbutatin-oxide (Vendex)	12,393	18,852	8.3	$685,830
horticultural oil (Petroleum Products)	4,574,953	224,253	98.1	$2,516,224
methidathion (Supracide)	41,888	26,477	11.6	$1,172,858
permethrin (Pounce)	9,339	41,500	18.2	$630,374
phosmet (Imidan)	120,207	41,478	18.2	$1,245,343
propargite (Omite)	266,220	119,406	52.3	$5,164,665
pyridaben (Pyramite)	1,972	7,388	3.2	$368,139
spinosad (Success)	3,424	34,698	15.2	$1,095,526

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the San Joaquin Valley is about $92.59

Table 2. Insecticide and Miticide Use on Almonds in the Northern San Joaquin Valley of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
abermectin (Agri-Mek, Clinch)	184	28,113	13.9	$920,871
azinphosmethyl (Guthion)	8,235	5,206	2.6	$171,127
Bacillus thuringiensis (Various Products)	2,721	32,333	16	$84,023
chlorpyrifos (Lorsban)	62,331	41,531	20.5	$1,179,305
clofentezine (Apollo)	523	4,738	2.4	$199,748
diazinon (Diazinon)	32,946	16,973	8.4	$304,420
esfenvalerate (Asana)	1,735	36,957	18.2	$315,400
fenbutatin-oxide (Vendex)	7,846	14,805	7.3	$434,191
horticultural oil (Petroleum Products)	2,809,807	144,923	71.5	$1,545,394
methidathion (Supracide)	7,875	7,757	3.8	$220,494
permethrin (Pounce)	10,259	63,759	31.5	$692,485
phosmet (Imidan)	8,815	3,615	1.8	$91,319
propargite (Omite)	97,282	58,351	28.8	$1,887,269
pyridaben (Pyramite)	123	743	0.4	$22,925
spinosad (Success)	604	4,951	2.4	$193,171

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the San Joaquin Valley is about $40.77.

Table 3. Insecticide and Miticide Use on Almonds in the Sacramento Valley of CA, 1999

Material*	**Lb (ai)**	**Acres Treated**	**% Acres Treated**	**Costs**
abermectin (Agri-Mek, Clinch)	4	5,463	5.3	$3,891
azinphosmethyl (Guthion)	17,231	10,711	10.3	$358,070
Bacillus thuringiensis (Various Products)	1,688	19,841	19.1	$52,140
chlorpyrifos (Lorsban)	8,996	13,268	12.8	$170,213
clofentezine (Apollo)	130	1,526	1.5	$3,284
diazinon (Diazinon)	28,648	14,230	13.7	$264,707
esfenvalerate (Asana)	1,307	25,068	24.1	$237,677
fenbutatin-oxide (Vendex)	2,448	4,698	4.5	$135,447
horticultural oil (Petroleum Products)	1,119,286	52,726	50.1	$615,608
methidathion (Supracide)	3,057	2,518	2.4	$85,595
permethrin (Pounce)	951	4,889	4.7	$64,220
phosmet (Imidan)	7,892	3,081	3	$81,757
propargite (Omite)	21,221	19,354	18.6	$411,686
pyridaben (Pyramite)	6	27	>1	$12,097
spinosad (Success)	382	6,243	6	$122,310

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the Sacramento Valley is about $25.67

Table 4. Insecticide and Miticide Use in an OP Free Pest Management System with Available Technology on Almonds in the Southern San Joaquin Valley with High PTB and NOW Populations

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
	Prompt harvest and orchard sanitation - mummy nut removal and destruction			
horticultural oil	8 gal	1	PTB, SJS	Dormant application
+			ERM, OBLR	May increased spider
esfenvalerate	3/4 pt		1	mites populations
(Asana XL)				
or				
permethrin	1/2 pt			
(Pounce 3.2 EC)				
pyriproxyfen	1 pt	1/2	SJS	Application at
(Esteem 0.86 EC)				crawler emergence
Bacillus thuringiensis	1 lb	2	PTB, OBLR	Bloom applications
(Dipel 2X, others)			FTLR	
or				
spinosad	1/2 pt	1		Post-bloom (OBLR)
(Success 2SC)				or May timing (PTB)
esfenvalerate	3/4 pt	1	NOW	Hull split application
(Asana XL)				In-season application
or				would cause increased
permethrin	1/2 pt			spider mite
(Pounce 3.2 EC)				populations
abermectin	1 pt	2	TSSM, PSM	About two
(Agri-Mek 0.15EC)				miticides would be
+				required with the use of
Horticultural oil at 0.25% by volume				in-season pyrethroid
or				insecticide
clofentezine	1/4 pt			
(Apollo 4SC)				
or				
propargite	10 lb			
(Omite 30W)				
or				
fenbutatin-oxide		1 lb		
(Vendex 50WP)				
pyriproxyfen	2 lb	3/4	Ants	
(Distance)				
or				
abermectin	1 lb			
(Clinch)				

Table 5. Insecticide and Miticide Use in an OP Free Pest Management System with Available Technology on Almonds in the Southern San Joaquin Valley with low PTB and NOW Populations

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
Prompt harvest and orchard sanitation - mummy nut removal and destruction				
horticultural oil	8 gal	1	PTB, SJS	Dormant application
+			ERM, OBLR	May increased spider
esfenvalerate (Asana XL)	3/4 pt	1		mites populations
or				
permethrin (Pounce 3.2 EC)	1/2 pt			
or				
spinosad (Success 2SC)	1/2 pt			
pyriproxyfen (Esteem 0.86 EC)	1 pt	1/3	SJS	Application at crawler emergence
Bacillus thuringiensis (Dipel 2X, others)	1 lb	2	PTB, OBLR FTLR	Bloom applications
or				
spinosad (Success 2SC)	1/2 pt	1	PTB, OBLR FTLR	Post-bloom (OBLR) or May timing (PTB)
abermectin (Agri-Mek 0.15EC)	1 pt	3/4	TSSM, PSM	About 3/4 miticides would be required without the use of in-season pyrethroids
+				
Horticultural oil at 0.25% by volume				
or				
clofentezine (Apollo 4SC)	1/4 pt			
or				
propargite (Omite 30W)	10 lb			
or				
fenbutatin-oxide (Vendex 50WP)	1 lb			
pyriproxyfen (Distance)	2 lb	1	Ants	
or				
abermectin (Clinch)	1 lb			

Table 6. Insecticide and Miticide Use in an OP Free Pest Management System with Available Technology on Almonds in the Northern San Joaquin Valley with High PTB and NOW Populations

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
	Prompt harvest and orchard sanitation - mummy nut removal and destruction			
horticultural oil	8 gal	1	PTB, SJS	Dormant application
+			ERM, OBLR	May increased spider
esfenvalerate	3/4 pt	1		mites populations
(Asana XL)				
or				
permethrin	1/2 pt			
(Pounce 3.2 EC)				
pyriproxyfen	1 pt	1/2	SJS	Application at
(Esteem 0.86 EC)				crawler emergence
Bacillus thuringiensis	1 lb	2	PTB, OBLR	Bloom applications
(Dipel 2X, others)			FTLR	
or				
spinosad	1/2 pt	1		Post-bloom (OBLR)
(Success 2SC)				or May timing (PTB)
esfenvalerate	3/4 pt	1	NOW	Hull split application
(Asana XL)				In-season application
or				would cause increased
permethrin	1/2 pt			spider mite
(Pounce 3.2 EC)				populations
abermectin	1 pt	1	TSSM, PSM	About one
(Agri-Mek 0.15EC)				miticides would be
+				required with the use of
Horticultural oil at 0.25% by volume				in-season pyrethroid
or				insecticide
clofentezine	1/4 pt			
(Apollo 4SC)				
or				
propargite	10 lb			
(Omite 30W)				
or				
fenbutatin-oxide	1 lb			
(Vendex 50WP)				
pyriproxyfen	2 lb	1/2	Ants	
(Distance)				
or				
abermectin	1 lb			
(Clinch)				

Table 7. Insecticide and Miticide Use in an OP Free Pest Management System with Available Technology on Almonds in the Northern San Joaquin Valley with low PTB and NOW Populations

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
Prompt harvest and orchard sanitation - mummy nut removal and destruction				
horticultural oil	8 gal	1	PTB, SJS	Dormant application
+			ERM, OBLR	May increased spider
spinosad (Success 2SC)	1/2 pt	1		
pyriproxyfen (Esteem 0.86 EC)	1 pt	1/3	SJS	Application at crawler emergence
Bacillus thuringiensis (Dipel 2X, others)	1 lb	2	PTB, OBLR FTLR	Bloom applications
or				
spinosad (Success 2SC)	1/2 pt	1	PTB, OBLR FTLR	Post-bloom (OBLR) or May timing (PTB)
abermectin (Agri-Mek 0.15EC)	1 pt	1/2	TSSM, PSM	About 1/2 miticides would be required without the use of in-season pyrethroids
+				
Horticultural oil at 0.25% by volume				
or				
clofentezine (Apollo 4SC)	1/4 pt			
or				
propargite (Omite 30W)	10 lb			
or				
fenbutatin-oxide (Vendex 50WP)	1 lb			
pyriproxyfen (Distance)	2 lb	1/2	Ants	
or				
abermectin (Clinch)	1 lb			

Table 8. Insecticide and Miticide Use in an OP Free Pest Management System with Available Technology on Almonds in the Sacramento Valley with High PTB and NOW Populations

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
	Prompt harvest and orchard sanitation - mummy nut removal and destruction			
horticultural oil	8 gal	1	PTB, SJS	Dormant application
+			ERM,OBLR	May increased spider
esfenvalerate	3/4 pt	1		mites populations
(Asana XL)				
or				
permethrin	1/2 pt			
(Pounce 3.2 EC)				
pyriproxyfen	1 pt	1/3	SJS	Application at
(Esteem 0.86 EC)				crawler emergence
Bacillus thuringiensis	1 lb	2	PTB, OBLR	Bloom applications
(Dipel 2X, others)			FTLR	
or				
spinosad	1/2 pt	1		Post-bloom (OBLR)
(Success 2SC)				or May timing (PTB)
esfenvalerate	3/4 pt	1	NOW	Hull split application
(Asana XL)				In-season application
or				would cause increased
permethrin	1/2 pt			spider mite
(Pounce 3.2 EC)				populations
abermectin	1 pt	1/2	TSSM, PSM	About 1/2
(Agri-Mek 0.15EC)				miticides would be
+				required with the use of
Horticultural oil at 0.25% by volume				in-season pyrethroid
or				insecticide
clofentezine	1/4 pt			
(Apollo 4SC)				
or				
propargite	10 lb			
(Omite 30W)				
or				
fenbutatin-oxide	1 lb			
(Vendex 50WP)				
pyriproxyfen	2 lb	1/4	Ants	
(Distance)				
or				
abermectin	1 lb			
(Clinch)				

Table 9. Insecticide and Miticide Use in an OP Free Pest Management System with Available Technology on Almonds in the Sacramento Valley with low PTB and NOW Populations

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
Prompt harvest and orchard sanitation - mummy nut removal and destruction				
horticultural oil	8 gal	1	PTB, SJS	Dormant application
+			ERM, OBLR	
spinosad	1/2 pt	1		
(Success 2SC)				
or				
Bacillus thuringiensis	1 lb	2	PTB, OBLR	Bloom applications
(Dipel 2X, others)				FTLR replacement for
				dormant application
pyriproxyfen	1 pt	1/4	SJS	Application at
(Esteem 0.86 EC)				crawler emergence
abermectin	1 pt	1/8	TSSM, PSM	Mites would not
(Agri-Mek 0.15EC)				be a problem
+				with about 1/8
Horticultural oil at 0.25% by volume				applications
or				
clofentezine	1/4 pt			
(Apollo 4SC)				
or				
propargite	10 lb			
(Omite 30W)				
or				
fenbutatin-oxide	1 lb			
(Vendex 50WP)				
pyriproxyfen	2 lb	1/2	Ants	
(Distance)				
or				
abermectin	1 lb			
(Clinch)				

Table 10. Insecticide and Miticide Use in an OP Free Pest Management System with Emerging Technology on Almonds in the Southern San Joaquin Valley with High PTB and NOW Populations

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
	Prompt harvest and orchard sanitation - mummy nut removal and destruction			
horticultural oil	8 gal	1	PTB, SJS ERM,OBLR	Dormant application
+				
spinosad (Success 2SC)	1/2 pt	1		
pyriproxyfen (Esteem 0.86 EC)	1 pt	1/3	SJS	Application at crawler emergence
Bacillus thuringiensis (Dipel 2X, others)	1 lb	2	PTB, OBLR FTLR	Bloom applications
or				
spinosad (Success 2SC)	1/2 pt	1		Post-bloom (OBLR)
acetamiprid (Assail 70WP)	1/5 lb	1	NOW	May timing Not registered
or				
thiacloprid (Calypso 4SC)	3/8 pt			Not registered
acetamiprid (Assail 70WP)	1/5 lb	1	NOW	Hull split timing
or				
thiacloprid (Calypso 4SC)	3/8 pt			
abermectin (Agri-Mek 0.15EC)	1 pt	1	TSSM, PSM	Reduced miticides would be required without use of pyrethroid insecticides
+				
Horticultural oil at 0.25% by volume				
or				
clofentezine (Apollo 4SC)	1/4 pt			
or				
propargite (Omite 30W)	10 lb			
or				
fenbutatin-oxide (Vendex 50WP)	1 lb			
or				
spirodicolfen (Envidor 2SC)	1pt			Not registered
or				
milbemectin (Mesa)	2pt			Not registered
pyriproxyfen (Distance)	2 lb	1	Ants	
or				
abermectin (Clinch)	1 lb			

Table 11. Insecticide and Miticide Use in an OP Free Pest Management System with Emerging Technology on Almonds in the Southern San Joaquin Valley with low PTB and NOW Populations

Material	**Rate Form./ac**	**# Appl./ Season.**	**Pest**	**Notes**
	Prompt harvest and orchard sanitation - mummy nut removal and destruction			
horticultural oil	8 gal	1	PTB, SJS	Dormant application
+			ERM, OBLR	
spinosad (Success 2SC)	1/2 pt	1		
pyriproxyfen (Esteem 0.86 EC)	1 pt	1/3	SJS	Application at crawler emergence
Bacillus thuringiensis (Dipel 2X, others)	1 lb	2	PTB, OBLR FTLR	Bloom applications
or				
spinosad (Success 2SC)	1/2 pt	1		Post-bloom (OBLR) or May timing (PTB)
acetamiprid (Assail 70WP)	1/5 lb	1	NOW	Hull split application timing
or				
thiacloprid (Calypso 4SC)	3/8 pt			
abermectin (Agri-Mek 0.15EC)	1 pt	3/4	TSSM, PSM	Reduced mitcides would be required without use of pyrethroid insecticide
+				
Horticultural oil at 0.25% by volume				
or				
clofentezine (Apollo 4SC)	1/4 pt			
or				
propargite (Omite 30W)	10 lb			
or				
fenbutatin-oxide (Vendex 50WP)	1 lb			
or				
spirodicolfen (Envidor 2SC)	1pt			Not registered
or				
milbemectin (Mesa)	2pt			Not registered
pyriproxyfen (Distance)	2 lb	1	Ants	
or				
abermectin (Clinch)	1 lb			

Table 12. Insecticide and Miticide Use in an OP Free Pest Management System with Emerging Technology on Almonds in the Northern San Joaquin Valley with High PTB and NOW Populations

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
	Prompt harvest and orchard sanitation - mummy nut removal and destruction			
horticultural oil	8 gal	1	PTB, SJS	Dormant application
+			ERM,OBLR	
spinosad (Success 2SC)	1/2 pt	1		
pyriproxyfen (Esteem 0.86 EC)	1 pt	1/3	SJS	Application at crawler emergence
Bacillus thuringiensis (Dipel 2X, others)	1 lb	2	PTB, OBLR FTLR	Bloom applications
or				
spinosad (Success 2SC)	1/2 pt	1		Post-bloom (OBLR) or May timing (PTB).
acetamiprid (Assail 70WP)	1/5 lb	1	NOW	Hull split application timing
or				
thiacloprid (Calypso 4SC)	3/8 pt			
abermectin (Agri-Mek 0.15EC)	1 pt	1/2	TSSM, PSM	Reduced miticides would be required without use of pyrethroid insecticides
+				
Horticultural oil at 0.25% by volume				
or				
clofentezine (Apollo 4SC)	1/4 pt			
or				
propargite (Omite 30W)	10 lb			
or				
fenbutatin-oxide (Vendex 50WP)	1 lb			
or				
spirodicolfen (Envidor 2SC)	1pt			Not registered
or				
milbemectin (Mesa)	2pt			Not registered
pyriproxyfen (Distance)	2 lb	1/2	Ants	
or				
abermectin (Clinch)	1 lb			

Table 13. Insecticide and Miticide Use in an OP Free Pest Management System with Emerging Technology on Almonds in the Northern San Joaquin Valley with low PTB and NOW Populations

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
Prompt harvest and orchard sanitation - mummy nut removal and destruction				
horticultural oil	8 gal	1	PTB, SJS	Dormant application
+			ERM,OBLR	
spinosad (Success 2SC)	1/2 pt	1		
pyriproxyfen (Esteem 0.86 EC)	1 pt	1/4	SJS	Application at crawler emergence
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1	PTB, OBLR FTLR	Bloom applications
or				
spinosad (Success 2SC)	1/2 pt	1/2		Post-bloom (OBLR) or May timing (PTB)
abermectin (Agri-Mek 0.15EC)	1 pt	1/4	TSSM, PSM	Mites would be a very minor pests
Horticultural oil at 0.25% by volume				
or				
clofentezine (Apollo 4SC)	1/4 pt			
or				
propargite (Omite 30W)	10 lb			
or				
fenbutatin-oxide (Vendex 50WP)	1 lb			
or				
spirodicolfen (Envidor 2SC)	1pt			Not registered
or				
milbemectin (Mesa)	2pt			Not registered
pyriproxyfen (Distance)	2 lb	1/2	Ants	
or				
abermectin (Clinch)	1 lb			

Table 14. Insecticide and Miticide Use in an OP Free Pest Management System with Emerging Technology on Almonds in the Sacramento Valley with High PTB and NOW Populations

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
Prompt harvest and orchard sanitation - mummy nut removal and destruction				
horticultural oil	8 gal	1	PTB, SJS ERM,OBLR	Dormant application
+				
spinosad (Success 2SC)	1/2 pt	1		
pyriproxyfen (Esteem 0.86 EC)	1 pt	1/3	SJS	Application at crawler emergence
Bacillus thuringiensis (Dipel 2X, others)	1 lb	2	PTB, OBLR FTLR	Bloom applications
or				
spinosad (Success 2SC)	1/2 pt	1		Post-bloom (OBLR) or May timing (PTB).
acetamiprid (Assail 70WP)	1/5 lb	1	NOW	Hull split application timing
or				Not registered
thiacloprid (Calypso 4SC)	3/8 pt			Not registered
abermectin (Agri-Mek 0.15EC)	1 pt	1/4	TSSM, PSM	Reduced miticides would be required without use of pyrethroid insecticides
+				
Horticultural oil at 0.25% by volume				
or				
clofentezine (Apollo 4SC)	1/4 pt			
or				
propargite (Omite 30W)	10 lb			
or				
fenbutatin-oxide (Vendex 50WP)	1 lb			
or				
spirodicolfen (Envidor 2SC)	1pt			Not registered
or				
milbemectin (Mesa)	2pt			Not registered
pyriproxyfen (Distance)	2 lb	1/2	Ants	
or				
abermectin (Clinch)	1 lb			

Table 15. Insecticide and Miticide Use in an OP Free Pest Management System with Emerging Technology on Almonds in the Sacramento Valley with low PTB and NOW Populations

Material	**Rate Form./ac**	**# Appl./ Season.**	**Pest**	**Notes**
Prompt harvest and orchard sanitation - mummy nut removal and destruction				
horticultural oil	8 gal	1	PTB, SJS ERM, OBLR	Dormant application
+				
spinosad (Success 2SC)	1/2 pt	1		
or				
Bacillus thuringiensis (Dipel 2X, others)	1 lb	2	PTB, OBLR FTLR	Bloom applications replacement for dormant application
pyriproxyfen (Esteem 0.86 EC)	1 pt	1/4	SJS	Application at crawler emergence
abermectin (Agri-Mek 0.15EC)	1 pt	1/8	TSSM, PSM	Mites would not be a problem with about 1/8 applications
+				
Horticultural oil at 0.25% by volume				
or				
clofentezine (Apollo 4SC)	1/4 pt			
or				
propargite (Omite 30W)	10 lb			
or				
fenbutatin-oxide (Vendex 50WP)	1 lb			
pyriproxyfen (Distance)	2 lb	1/2	Ants	
or				
abermectin (Clinch)	1 lb			

BROCCOLI

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California produces over 90% of the broccoli in the United States and over 80% of California's broccoli is grown along the coast. The lower desert and southern San Joaquin Valley areas produce about 20% of California's broccoli crop. Production in the coast region is year round, whereas the lower desert production areas are limited to the winter and the southern San Joaquin Valley to the fall. Most of the broccoli produced is grown for the fresh market, but a limited amount is produced for the frozen, processed (soup, etc.) and lightly processed (ready-to-eat) markets.

Variations in climate, intended use and region can all influence pest problems and crop management options. Many insect pests of broccoli can inflict serious economic damage if not properly managed. The major pests of broccoli include cabbage aphid, diamondback moth, cabbage looper, imported cabbage worm, beet armyworm, silverleaf whitefly and cabbage maggot. Silverleaf whitefly and cabbage maggot can be important pests in specific production areas and times of the year. If uncontrolled, all of these pests may cause economic damage to some degree every year. Occasional pests of broccoli include flea beetles, springtails, symphylans bulb mites, cutworms, wireworms, green peach aphids, turnip aphids and leafminers. These pests may cause some economic damage in various growing areas at sporadic intervals.

Cabbage Aphid (CA),, *Brevicoryne brassicae*

Cabbage aphid is an important pest of broccoli throughout the year in the coast growing regions. CA reproduces rapidly and damaging populations can develop quickly. However, infestations during mid-spring through the summer tend to be more severe than fall and winter infestations. In the lower desert and southern San Joaquin Valley, CA infestations can occur throughout the growing season. However, CA is not as serious a pest in the lower desert and southern San Joaquin Valley as in the coast growing regions. CA populations are often clumped along field edges or similar borders. This allows for the possibility of spot treatment that can preserve natural parasites and predators. However, spot treatment to preserve beneficial insects is not widely practiced. Damage from CA includes discolored and distorted foliage, but more importantly CA infest the developing broccoli heads making them unmarketable.

Between thinning and head formation, broccoli can tolerate CA populations as high as 100 per plant without yield loss. Once the head formation begins, control of CA is essential since the presence of even a few aphids can make heads unfit for market. CA colonies in heads of broccoli cannot be removed by processing. CA management relies on repeated applications of organophosphate (OP) insecticides, e.g. chlorpyrifos (Lorsban), dimethoate (Dimethoate) and oxydemeton-methyl (Metasystox-R) and/or neonicotinoid, imidacloprid (Provado). Metasystox-R is highly effective and is the material of choice for control of established CA populations.

Diamondback Moth (DBM), *Plutella xylostella*

Diamondback moth is a common pest of broccoli in California, particularly in the coast region and the southern San Joaquin Valley. Females usually lay single eggs on the underside of leaves, which can be very difficult to identify. Larvae can damage small plants early in the season, but the more severe damage occurs when larvae infest the developing head. DBM larvae chew holes in growing points on young plants and bore into the heads of broccoli causing serious damage in the form of stunted plants and contaminated heads. DBM has the ability to damage broccoli year round, with large populations occuring from spring through fall. The DBM lifecycle is well synchronized with its natural enemies. In the southern coast region the larval parasitoid, *Diadegma insularis*, along with the egg parasitoid, *Trichogramma pretiosum,* can substantially contribute to DBM control. However, these beneficial insects alone will not achieve economic control. Most fields will be infested with DBM requiring repeated applications with insecticides to achieve economic control. Since 1997 spinosad (Success) has become a principal control tool for DBM in California. In the southern San Joaquin Valley tebufenozide (Confirm) has been applied during the early season for DBM control. Lorsban, *lambda* cyhalothrin (Warrior) and esfenvalerate (Asana) are used against the early instars of this pest as well as *Bacillus thuringiensi* (Bt), (Dipel and others).

Cabbage Looper and Imported Cabbageworm

Cabbage Looper (CL), *Trichoplusia ni*
Imported Cabbageworm (ICW), *Pieris rapae*

Cabbage looper is an important pest of broccoli. CL occurs from April through October, with heavier infestation during the fall. CL damages broccoli by skeletonizing leaves, boring into heads and contaminating the marketable heads with their bodies and frass, rendering the commodity unmarketable. ICW can be found in all growing regions, although they pose the greatest threat to broccoli in the lower desert and southern San Joaquin Valley. In the lower desert areas ICW is an important pest in the cooler months of October through December, compared to the southern San Joaquin Valley where infestations are usually greatest in the fall.

Damage caused by ICW is similar to that caused by CL. ICW larvae bore into heads leaving fecal pellets that contaminate broccoli heads. Seedlings may be destroyed or their growth stunted. A limited amount of damage is tolerated between thinning and head formation. Once plants begin head formation even low numbers of ICW can lead to serious economic damage. Low densities of ICW require insecticide applications to maintain population below damaging levels. While various natural parasites, viruses and bacterial diseases can help keep populations below damaging levels; chemical control programs are often necessary. Success, Lorsban, methomyl (Lannate), Warrior and Asana are used against these pests as well as Dipel.

Beet Armyworm (BAW), *Spodoptera exigua*

Beet armyworm attacks broccoli in the coast from June through October, especially in southern California. In the lower desert and southern San Joaquin Valley, BAW infestations peak in the fall. This pest is particularly injurious during stand establishment in the lower desert. The first instar BAW larvae feed in small groups and can skeletonize leaves or even consume the entire seedling. As the larvae mature, they move on to older tissue and bore into the center of the developing head. Without the use of chemical control measures, BAW infestation during stand establishment can result in total stand loss. Timing of the treatment can be very important and effort should be made to apply insecticides when BAW are most active. The selective insecticide Bt, which is commonly used to control CL and ICW, is not effective against BAW and resistance to other insecticides has also been reported. Control programs rely on Success, Lorsban, Lannate, Warrior, and Asana.

Silverleaf Whitefly (SLW), *Bemisia Argentifloii*

Silverleaf whitefly thrives throughout the lower desert region of California. Since 1991 it has been an important pest of broccoli in the lower desert and more recently has begun to cause damage to broccoli grown in the southern San Joaquin Valley. SLW develops on cucurbits and cotton. When these crops are harvested in the fall, SLW often disperse to nearby broccoli fields. SLW damage to the broccoli is stunted growth and discoloration of foliage, as well as sticky “honeydew" deposits left by the developing nymphs. Typical damage is reduced yield and delayed harvest timing. In response to the damaging population of SLW, growers routinely apply a preventative systemic imidacloprid (Admire) treatment at the time of broccoli planting. Although it is still a significant pest, the introduction of Admire in the early 1990’s has significantly reduced the damaged caused by SLW.

Cabbage Maggot (CM), *Delia radicum*

Cabbage maggot is a problem primarily for broccoli growers in the coast region throughout the year. Rotation with other cole crops, plus the cool moist coast climate, encourages development of maggot populations. Injury from CM often damages or destroys root systems and can cause stunting, yellowing, wilting, and may result in plant death. Injury from CM is most serious on seedlings and can also provide an entry point for some plant pathogens. Since soil moisture is a key to developing maggot populations, spring and summer crops face the greatest potential for severe losses. Control of this pest relies exclusively on OP insecticides, primarily Lorsban and occasionally diazinon (Diazinon). Without OP insecticides significant stand loss is expected in the spring and summer crops along the coast. There is not viable, chemical, cultural or biological control available to control this pest at this time other than OP insecticides.

Palestriped Flea Beetle (FB), *Systena bland*

Flea beetle damage is usually restricted to seedling stage. The lower desert region is the only region that regularly treats for FB. A common source of FB populations is adjacent alfalfa fields. As the alfalfa fields are harvested in fall, flea beetles disperse to young broccoli fields where they can do considerable damage. Typically only a single insecticide application, at seedling stage or just prior to thinning, is required for control. The most common insecticides are Diazinon, Lorsban, permethrin (Pounce) and Asana. All of the insecticides used for FB control are also used to manage other broccoli pests.

Occasional Pests

Although pests such as flea beetles, springtails, symphylans, bulb mites, cutworms, wireworms, green peach aphids, turnip aphids and leafminers are only occasional pests, they can be devastating to the specific fields affected. Of these, control of the soil organisms such as springtails, symphylans and bulb mites is most heavily dependent on OP insecticides.

Current Pest Management Program

Coast Region

Broccoli is grown throughout the year along the central coast. The majority of broccoli is produced in Monterey, San Luis Obispo, San Benito and Santa Clara counties in the central coast region while the majority of broccoli in the south coast region is grown in Santa Barbara County. The central and south coast areas are treated here as one region (coast region) due to the shared harvest pattern and the similarity of insect pest problems associated with the coast climate. However, it is important to note along the coast region insect pest problems may differ substantially according to climate, season, kind of crop grown on adjacent fields and the nature of recurrent insect pest problems. The coast's cool growing climate allows for the year-round production of broccoli and has the greatest effect on the composition of insect pest problems.

Aphids, especially CA, are a particular problem along the central coast preferring the mild climates of more northerly coastal areas such as the Salinas Valley. Present year-round in this region, aphids must be monitored regularly, especially during head formation. In the warmer climate of the south coast, aphid populations usually peak in winter with populations declining in late spring and becoming insignificant during July and August.

Control of aphids relies heavy on OP insecticides. Metasystox-R was applied to over 79% of the broccoli growing acres in the coast region in 1999 (Table 1). However, due to the potential for resistance, other compounds are used sequentially. Dimethoate and Lorsban were used on over 53% and 45% of the broccoli produced in the coast region in 1999, respectively. A move toward the use of more selective compounds has seen an increase in the use of non-OP insecticides. Admire and Provado are neonicotinoid insecticides that were applied on greater than 25% of the acreage treated in 1999. Provado is usually applied late in the season due to its relatively short pre-harvest interval (7 days). The use of Admire as a soil treatment for aphid control is cost prohibitive in the coast region.

Lepidopterous pests are more of a problem in the lower desert and southern San Joaquin Valley than the coast region. CL, ICW and BAW can all develop to economically damaging levels in the coast region during various times of the year. However, DBM is the most important lepidopterous pest in the coast region. With the potential to reach devastating levels quickly, especially in the late summer, repeated chemical applications are often required to maintain adequate control of this pest. Success has proven to be an effective insecticide for DBM and was applied to over 50% of coast broccoli fields. Asana is applied for control of CL, ICW and BAW. In 1999, about 28% of the broccoli grown in the coast region were treated with a pyrethroid insecticide (Ammo, Asana, Warrior, Pounce or Scout X-TRA).

Control of CM relies primarily on Lorsban. Lorsban was applied to over 45% of coast broccoli fields in 1999. In addition to CM control, Lorsban was also used for lepidopterous control. The average insecticide (material) cost per acre for broccoli production in the coast region in 1999 was about is $48.00.

Southern San Joaquin Valley and Lower Desert Region

Broccoli production in the southern San Joaquin Valley is concentrated mostly in Fresno County with the southern San Joaquin Valley producing about 8% of California's broccoli crop in 1999. Imperial and Riverside counties in the lower desert region produced 9% of the state's broccoli crop. Broccoli is planted in late summer and fall in these regions. Southern San Joaquin Valley may harvest twice, once in the fall and once in the spring, whereas the lower desert region has an extended harvest from December into early spring. Due to the warm dry climate, and the different composition of adjacent fields, insect pest problems in the southern San Joaquin Valley and lower desert region are quite distinct from the coast region. SLW and FB are a major concern in the lower desert region and the southern San Joaquin Valley. In addition, warmer temperatures allow for multiple generations of lepidopterous pests that pose an increased threat.

SLW reached devastating levels in the lower desert region in some broccoli fields in the early 1990's and is an increasing threat in the southern San Joaquin Valley. Beneficial insects, delayed planting and maintaining good sanitation can all help reduce SLW damage. The registration of the neonicotinoid insecticides and the suppression of SLW on cotton, alfalfa and other crops in the area have reduced the SLW population on broccoli. However, insecticide treatments are required to maintain populations below economically damaging levels. Over 39% of the broccoli grown in the lower desert region were treated with Admire and/or Provado in 1999 (Table 2). Admire is applied as a systemic soil treatment at planting and is effective on immature stages. Provado, a foliar treatment, is applied later in the season since it is not effective against heavy populations. Once populations of SLW are established, the light populations can be controlled with endosulfan (Thiodan). However for moderate to heavy populations, Thiodan must be combined with other products such as Lannate.

Lepidopterous pests have historically been, and continue to be, the most significant pests of broccoli in the lower desert region and southern San Joaquin Valley. ICW, CL, BAW and to a lesser extent DBM are present throughout the year with heavier infestations likely in the fall. Because Dipel targets lepidopterous pests specifically, it can be used with beneficial insects for effective control of low to moderate populations of ICW and CL. In 1999 over 39% of the broccoli in these regions were treated with Dipel.

Control of BAW and high DBM, ICW and CL populations rely on Lannate and pyrethroid insecticides. Lannate was applied to over 48% of the broccoli in the lower desert region and southern San Joaquin Valley, usually mixed with a pyrethroid. The major pyrethroid insecticides applied were Asana, Pounce, Warrior and cypermethrin (Ammo) at 42%, 52%, 62% and 5% of the acres treated, respectively. Success combined with Dipel or Asana or Pounce provides effective control of lepidopterous pests. Success was applied to 96% of the broccoli in the southern San Joaquin Valley and lower desert region. An emergency exemption in 1997 and

1998 allowed the use of Confirm for control of BAW and DBM. Confirm is an insect growth regulator that is highly selective for lepidopterous pests and does not disrupt the beneficial insect complex. Confirm was used on 11% of the broccoli in these regions. Diazinon is also used for lepidopterous pests and seedling pests, e.g. FB and symphylans, and was used on 51% of broccoli in these regions. Lorsban was sprayed 44% of the time and is effective for FB as well. The average insecticide (material) cost per acre for broccoli production in the San Joaquin Valley and desert regions in 1999 was about $92.00.

OP Free – Pest Management Program with Available Technology

The OP free programs below were constructed with currently registered insecticides for immediate implementation and without regard to resistance management consequences. A pest management program in broccoli, without OP insecticides, would rely on pyrethroid (Asana XL, Pounce 3.2EC and Warrior T and others), carbamate (Lannate SP) insecticides and *Bacillus thuringienesis* (Dipel 2X or others) for lepidopterous pests and Provado or Admire for aphids and whiteflies. However, at present there is no non-OP insecticide available for control of CM. It is anticipated that CM would cause considerable stand loss in the coast region.

Coast Region

The most important insect pests of broccoli in the coast region are CA and CM with lepidopterous larvae being a major concern in summer and fall crops. CA in the winter is of less concern and would require a single application of Provado (Table 3). In the spring crop, two applications of Provado would be required for control, while in the summer and fall crops a single systemic application of Admire would be required at planting (Table 4, 5, and 6). In addition to Admire for CA control in the summer and fall crops, Lannate would provide additional control when applied for other pests, such as lepidopterous larvae. Most fields have a combination of lepidopterous pests that include CL, ICW, DBM or BAW and would require multiple applications of insecticides. Lepidopterous larval control would rely on an application of Success or Confirm, an application pyrethroid and an application of Lannate combined with Dipel. Fields with low CL or ICW populations can use Dipel alone. It is projected that about two to three applications per acre per season would be required for control of lepidopterous pests. Control of seedling pests, except CM, would rely on Asana, Pounce, Warrior or other pyrethroid insecticides. It is anticipated that about 25% of the fields would need to be treated annually for seedling pests.

Since soil moisture is low during the fall plantings, no insecticide applications are required for CM control. However, in the spring and summer crops CM would be a major concern. CM would again become less of a concern during the fall crop. Since CM control relies exclusively on OP insecticides, and no suitable OP replacement products are currently registered on broccoli for CM control, it is estimated that there would be about 30% stand loss for the spring crop and 20% stand loss for the summer crop and about 10% stand loss for the fall crop due to uncontrolled CM infestation.

Southern San Joaquin Valley and Lower Desert Region

The most important insect pests of broccoli for winter production in the lower desert region and fall production in the southern San Joaquin Valley are SLW and lepidopterous larvae including BAW, CL, ICW and to a lesser extent DBM. Control of SLW would rely on a systemic application of Admire at planting. Admire would also indirectly control CA, although aphids are not a major concern in these areas. Those CA not controlled by the Admire treatment would be controlled by Lannate that would be directed against lepidopterous larvae. Control of seedling pests, particularly FB in the lower desert region and BAW larvae in southern San Joaquin Valley, would rely on a single application of a pyrethroid such as Asana, Pounce, or Warrior (Table 7).

Most fields have a combination of lepidopterous pests with high populations of CL, ICW, DBM or BAW and would require multiple applications of insecticides. Control would rely on an application of Success or Confirm, an application of pyrethroid, and about a half application of Lannate combined with Dipel. Fields with low CL or ICW populations can again use Dipel alone. It is projected that about two and half applications per acre per season would be required for control of lepidopterous pests.

OP Free – Pest Management Program with Emerging Technology

The IPM programs below were constructed with currently registered insecticides and/or insecticides that are anticipated to be registered within four to five years. The pest management program with emerging technology is intended to produce a stable long-term program that would allow for much greater impact of beneficial insects and mites on the pest populations. The pest management program would maintained low pest densities over time and prevent large pest density oscillations.

Coast Region

The most important insect pests of broccoli in the coast region are CA and CM with lepidopterous larvae being a major concern in summer and fall crops. Since insect problems are of minor concern in the winter crop, only about two applications of insecticides would be required for control (Table 8). CA control would rely on Provado, while lepidopterous larvae control would rely on a pyrethroid or Success application depending on the lepidopterous pest (Table 8). Since soil moisture is low during the plantation of fall and winter broccoli, no insecticide applications are required for CM control (although CM can be a small problem for fall crops). However, in the spring and summer crops CM would be a major concern as the spring and summer rains raise soil moisture.
It is anticipated that cyromazine (Trigard) will be registered on broccoli within four or five years. Trigard applied at transplanting or in the seed line provides effective CM control. In addition to Trigard, fipronil (Regent) provides excellent control and is registered for seedcorn maggot thought the mid-west. However, registration of Regent is not expected in California at this time. CA and lepidopterous larvae would also increase in populations as the weather warms. In the spring crop, two applications of Provado would be required for control of CA, while in the summer and fall crops a single systemic application of Admire would be required at planting

plus about half of an application of Provado (Tables 9, 10 and 11). Control of CL, ICW, DBM or BAW would rely on four to five applications of Success or methoxyfenozide (Intrepid), indoxacarb (Avaunt), Proclaim (emamectin benzoate), and Dipel used alone or in combination. Fields with low CL or ICW populations can use Dipel alone with two to three applications per acre per season. Control of seedling pests such as FB would reply on Thiodan. It is anticipated that about 25% of the fields would need to be treated annually of seedling pests.

Southern San Joaquin Valley and Lower Desert Regions

The most important insect pests of broccoli for winter production in the lower desert region and fall production in the southern San Joaquin Valley are SLW and lepidopterous larvae that is composed of BAW, CL, ICW and to a lesser extent DBM. Control of SLW would rely on a systemic application of Admire at planting (Table 12). If SLW populations increase during the season, Provado would be applied to suppress the population. Admire and Provado would indirectly control CA; aphids are not a major concern in these areas and do not require additional treatments.

Control of lepidopterous pests would require multiple applications of reduced risk insecticides. Most fields have a combination of lepidopterous pests and high populations of CL, ICW, DBM or BAW would be expected particularly in fall plantings in the southern San Joaquin Valley. Control would rely on three applications of Success, Intrepid, Avaunt, or Proclaim. In addition, an application of Dipel would be requested alone or in combination. Field with high populations of BAW and DBM would rely on Success and fields with high populations of CL and ICW would rely on Intrepid, Avaunt or Proclaim combined with Dipel. Fields with low CL or ICW populations can use Dipel alone.

Control of seedling pests, particularly FB in the lower desert region and BAW larvae in southern San Joaquin Valley, would rely on about 1/4 of an application of Thiodan and about 1/4 of an application of a pyrethroid insecticide. The early season application of Thiodan or pyrethroid would not have a great impact upon beneficial insects. Beneficials should be able to re-colonize the field as the broccoli matures and cause increased natural mortality.

Addendum

A number of products have been registered in broccoli since the economic analysis. These include acetamiprid (Assail), emamectin benzoate (Proclaim) and indoxacarb (Avaunt). Proclaim and Avaunt have lepidopteran larval activity and will be added to the existing reduced risk insecticides, e.g., tebufenozide (Confirm), spinosad (Success) and *Bacillus thuringiensis* (various products). The registration of these products will increase the number of available insecticides and hopefully reduce or contain costs. Assail has lepidopteran larval as well as aphid activity. Assail will be useful when multiple pests, i.e., aphid/whiteflies and lepidopteran pests, are present simultaneously. Assail may have a significant impact on broccoli production. However, none of these new products control cabbage maggot and cabbage maggot injury is responsible for the majority of increased economic cost with the removal of OP insecticides. Effective control of cabbage maggot will have to wait for the registration of cyromazine (Trigard).

Table 1. Insecticide and Miticide Use on Broccoli in the Coast Region of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
azadirachtin (Neemix)	24	1,788	1.5	$27,754
Bacillus thuringiensis (Various Proucts)	369	3,887	3.3	$11,382
chlorpyrifos (Lorsban)	63,159	52,238	44.9	$1,194,964
cypermethrin (Ammo)	167	2,030	1.8	$19,384
diazinon (Diazinon)	4,553	3,531	3	$42,073
dimethoate (Dimethoate)	29,195	62,355	53.6	$287,569
disulfoton (Di-Syston)	5,932	5,186	4.5	$64,061
endosulfan (Thiodan)	402	401	0.3	$4,703
esfenvalerate (Asana)	795	21,431	18.4	$144,511
fonofos (Dyfonate)	5,889	3,148	2.7	$58,894
imidacloprid (Admire, Provado)	1,822	29,380	25.3	$620,404
lambda cyhalothrin (Warrior)	120	4,594	4	$50,274
malathion (Malathion)	504	293	0.3	$2,757
methomyl (Lannate)	2,060	3,077	2.7	$45,769
naled (Dibrom)	14,658	9,214	7.9	$153,467
oxydemeton-methyl (Metasystox-R)	44,669	91,429	78.6	$1,451,746
permethrin (Pounce)	783	8,200	7.1	$52,852
pyrethrins (Pyrenone)	18	1,733	1.5	$28,960
spinosad (Success)	3,609	57,544	49.5	$1,154,880
tebufenozide (Confirm)	32	291	0.3	$3,015
thiodicarb (Larvin)	346	558	0.5	$1,191
tralomethrin (Scout X-TRA)	92	4,080	3.5	$29,229

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre planted for the Coast Regions is about $47.69.

Table 2. Insecticide and Miticide Use on Broccoli in the San Joaquin Valley and Desert Regions of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
azadirachtin (Neemix)	7	522	1.8	$7,997
Bacillus thuringiensis (Various Proucts)	902	11,557	39	$27,860
chlorpyrifos (Lorsban)	14,618	12,955	43.7	$276,567
cypermethrin (Ammo)	117	1,350	4.6	$13,618
diazinon (Diazinon)	10,175	15,212	51.4	$94,018
dimethoate (Dimethoate)	1,122	2,982	51.4	$11,048
disulfoton (Di-Syston)	1,407	1,407	5	$15,196
endosulfan (Thiodan)	1,555	1,854	6.3	$18,198
esfenvalerate (Asana)	497	12,533	42.3	$90,328
imidacloprid (Admire, Provado)	2,522	11,757	39.7	$858,563
lambda-cyhalothrin (Warrior)	481	18,418	62.2	$201,852
malathion (Malathion)	2,877	1,823	6.2	$15,738
methomyl (Lannate)	9,302	14,283	48.2	$206,690
naled (Dibrom)	760	615	2.1	$7,962
oxydemeton-methyl (Metasystox-R)	2,130	5,267	17.8	$69,238
permethrin (Pounce)	759	15,271	51.6	$51,260
pyrethrins (Pyrenone)	2	59	0.2	$2,880
spinosad (Success)	1,999	28,416	95.9	$639,552
Tebufenozide (Confirm)	360	3,261	11	$33,992
Thiodicarb (Larvin)	2,239	2,723	9.2	$7,702
Tralomethrin (Scout X-TRA)	15	742	2.5	$4,750

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre planted for the San Joaquin Valley and Desert Regions is about $92.35.

Table 3. Insecticide Use in an OP Free Pest Management Program with Available Technology on Broccoli in the Coast Region for Winter Production

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
esfenvalerate (Asana XL)	1/2 pt	1/2	Lepidopterous Larvae Seedling Pests	May disrupt biological control
or				
permethrin (Pounce 3.2 EC)	1/4 pt			
or				
lambda-cyhalothrin (Warrior T)	1/8 pt			
or				
bifenthrin (Capture 2EC)	1/4 pt			
spinosad (Success 2SC)	1/2 pt	1/2	Lepidopterous Larvae	
or				
tebufenozide (Confirm 2F)	1/2 pt			
imidacloprid (Provado 1.6F)	1/4 pt	1	Aphids	

Table 4. Insecticide Use in an OP Free Pest Management Program with Available Technology on Broccoli in the Coast Region for Spring Production

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
esfenvalerate (Asana XL)	1/2 pt	1	Lepidopterous larvae and Seedling pests	May disrupt biological control
or				
permethrin (Pounce 3.2 EC)	1/4 pt			
or				
lambda-cyhalothrin (Warrior T)	1/8 pt			
or				
bifenthrin (Capture 2EC)	1/4 pt			
spinosad (Success 2SC)	1/2 pt	1	Lepidopterous larvae	
or				
tebufenozide (Confirm 2F)	1/2 pt			
methomyl (Lannate SP)	1 lb	1/2	Lepidopterous larvae and Aphids	May disrupt biological control
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1/2	Lepidopterous larvae	
imidacloprid (Provado 1.6F)	1/4 pt	2	Aphids	

Table 5. Insecticide Use in an OP Free Pest Management Program with Available Technology on Broccoli in the Coast Region for Summer Production

Material	**Rate Form/ac**	**# Appl./ Season**	**Pest**	**Notes**
esfenvalerate (Asana XL)	1/2 pt	2	Lepidopterous larvae and Seedling Pests	May disrupt biological control
or				
permethrin (Pounce 3.2 EC)	1/4 pt			
or				
lambda-cyhalothrin (Warrior T)	1/8 pt			
or				
bifenthrin (Capture 2EC)	1/4 pt			
spinosad (Success 2SC	1/2 pt	1	Lepidopterous larvae	
or				
tebufenozide (Confirm 2F)	1/2 pt			
methomyl (Lannate SP)	1 lb	1	Lepidopterous larvae and Aphids	May disrupt biological control
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1/2	Lepidopterous larvae	
imidacloprid (Admire 2F)	1 pt	1	Aphids	

Table 6. Insecticide Use in an OP Free Pest Management Program with Available Technology on Broccoli in the Coast Region for Fall Production

Material	**Rate Form/ac**	**# Appl./ Season**	**Pest**	**Notes**
esfenvalerate (Asana XL)	1/2 pt	2	Lepidopterous larvae	May disrupt biological control
or				
permethrin (Pounce 3.2 EC)	1/4 pt			
or				
lambda-cyhalothrin (Warrior T)	1/8 pt			
or				
bifenthrin (Capture 2EC)	1/4 pt			
spinosad (Success 2SC)	1/2 pt	1	Lepidopterous larvae	
or				
tebufenozide (Confirm 2F)	1/2 pt			
methomyl (Lannate SP)	1 lb	2	Lepidopterous larvae and Aphids	May disrupt biological control
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1	Lepidopterous larvae	
imidacloprid (Admire 2F)	1 pt	1	Aphids	

Table 7. Insecticide Use in an OP free Pest Management Program with Available Technology on Broccoli in the Lower Desert for Winter Production and Southern San Joaquin Valley for Fall Production

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
esfenvalerate (Asana XL)	1/2 pt	2	Lepidopterous larvae, FB and Seedling pests	May disrupt biological control
or				
permethrin (Pounce 3.2 EC)	1/4 pt			
or				
lambda-cyhalothrin (Warrior T)	1/8 pt			
or				
bifenthrin (Capture 2EC)	1/4 pt			
methomyl (Lannate SP)	1 lb	1	Lepidopterous larvae and Aphids	May disrupt biological control
spinosad (Success 2SC)	1/2 pt	1	Lepidopterous larvae	
or				
tebufenozide (Confirm 2F)	1/2			
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1/2	Lepidopterous larvae	
imidacloprid (Admire 2F)	1 pt	1	Aphids and Whiteflies	

Table 8. Insecticide Use in an OP Free Pest Management Program with Emerging Technology on Broccoli in the Coast Region for Winter Production

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
spinosad (Success 2SC)	1/2 pt	1	Lepidopterous larvae	
or				
methoxyfenozide (Intrepid 2F)	1/2 pt			Not registered
or	1/4 lb			
indoxacarb (Avaunt 30 WDG)				Not registered
or	1/4 pt			
emamectin benzoate (Proclaim 5WDG)				Not registered
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1/2	Lepidopterous larvae	
imidacloprid (Provado 1.6F)	1/4 pt	1	Aphids and Whiteflies	

Table 9. Insecticide Use in an OP Free Pest Management Program with Emerging Technology on Broccoli in the Coast Region for Spring Production

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
spinosad (Success 2SC)	1/2 pt	2	Lepidopterous larvae	
or				
methoxyfenozide (Intrepid 2F)	1/2 pt			Not registered
or				
indoxacarb (Avaunt 30 WDG)	1/4 lb			Not registered
or				
emamectin benzoate (Proclaim 5WDG)	1/4 pt			Not registered
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1/4	Lepidopterous larvae	
imidacloprid (Provado 1.6F)	1/4 pt	2	Aphids and Whiteflies	
cyromazine (Trigard 75WP)	1/6 lb	1	Cabbage maggot	Not registered
endosulfan (Thiodan 50W)	2 lb	1/4	Aphids,Whiteflies, FB, Springtails and Garden symphylans	

Table 10. Insecticide Use in an OP Free Pest Management Program with Emerging Technology on Broccoli in the Coast Region for Summer Production

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
spinosad (Success 2SC) or	1/2 pt	3	Lepidopterous larvae	
methoxyfenozide (Intrepid 2F) or	1/2 pt			Not registered
indoxacarb (Avaunt 30 WDG) or	1/4 lb			Not registered
emamectin benzoate (Proclaim 5WDG)	1/4 pt			Not registered
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1/4	Lepidopterous larvae	
imidacloprid (Admire 2F/ Provado1.6F)	1 pt	1 1/2	Aphids and Whiteflies	
cyromazine (Trigard 75WP)	1/6 lb	1	CM	Not registered
endosulfan (Thiodan 50W)	2 lb	1/4	Aphids, Whiteflies, FB Springtails and Garden Symphylans	

Table 11. Insecticide Use in an OP Free Pest Management Program with Emerging Technology on Broccoli in the Coast Region for Fall Production

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
spinosad (Success 2SC)	1/2 pt	3	Lepidopterous larvae	
or				
methoxyfenozide (Intrepid 2F)	1/2 pt			Not registered
or				
indoxacarb (Avaunt 30 WDG)	1/4 lb			Not registered
or				
emamectin benzoate (Proclaim 5WDG)	1/4 pt			Not registered
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1/4	Lepidopterous larvae	
imidacloprid (Admire 2F/ Provado1.6F)	1 pt	1 1/2	Aphids and Whiteflies	
cyromazine (Trigard 75WP)	1/6 lb	1	CM	Not registered
endosulfan (Thiodan 50W)	2 lb	1/4	Aphids,Whiteflies FB, Springtails and Garden symphylans	

Table 12. Insecticide Use in an OP Free Pest Management Program with Emerging Technology on Broccoli in the Lower Desert for Winter Production and Southern San Joaquin Valley for Fall Production.

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
spinosad (Success 2SC)	1/2 pt	3	Lepidopterous larvae	
or				
methoxyfenozide (Intrepid 2F)	1/2 pt			Not registered
or				
emamectin benzoate (Proclaim 5WDG)	1/4 pt			Not registered
or				
indoxacarb (Avaunt 30 WDG)	1/4 lb			Not registered
Bacillus thuringiensis (Dipel 2X)	1 lb	1	Lepidopterous larvae	
imidacloprid (Admire 2F)	1 pt	1	Aphids and Whiteflies	
imidacloprid (Provado 1.6F)	1/4 pt	1/4	Aphids and Whiteflies	
endosulfan (Thiodan 50W)	2 lb	1/4	Aphids,Whiteflies, FB, Springtails and Garden symphylans	
esfenvalerate (Asana XL)	1/2 pt	1/4	Aphids,Whiteflies, and FB,	May disrupt biological control
or				
permethrin (Pounce 3.2 EC)	1/4 pt			
or				
lambda-cyhalothrin (Warrior T)	1/8 pt			
or				
bifenthrin (Capture 2EC)	1/4 pt			

CARROTS

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California produces about 75% of the carrots grown in the United States on over 95,000 acres. Carrots are grown year-round in California at various geographic locations. The majority of carrots are produced in southern San Joaquin Valley (45%), lower desert (31%) and coast region (20%). Insecticide use patterns and insect problems vary among the production areas. Most infestation results from dispersal from adjacent crops such as cotton, alfalfa and melons. However, few insecticide applications are used on carrots. The major insect pests include aphids (especially the green peach aphid), flea beetle, salt marsh caterpillar, cutworms and whiteflies.

Aphids

Aphids are pests in carrots throughout California, but species complex can vary by growing area. All parts of the carrot plant may become infested with one or more aphid species. Aphid populations do not often reach economically damaging levels in California carrot fields. However, when aphids have needed insecticide treatments in carrots, organophosphate (OP) insecticides have been most frequently chosen for control. A variety of common predators and parasites attack aphids in carrots. Lady beetles, green lacewing larvae and syrphid fly larvae are frequently found associated with aphid colonies. Aphids are also attacked by a very prolific parasitic wasp, *Lysiphlebus testaceipes*. Entomopathogenic fungi such as *Beauvaria bassiana* and *Paecilomyces fumosoroseus* also attack aphids. However, entomopathogenic fungi require high relative humidity to be efficacious.

Green Peach Aphid (GPA), *Myzus persicae*

The green peach aphid is commonly found in carrots in all production areas. In the lower desert region, GPA are found during the winter and spring while GPA are found during the spring and fall in coastal areas. GPA is a medium-sized aphid that is often uniformly pale green in color. GPA may be present at times in yellow, pinkish or red forms. The red morphological types are less susceptible than the green types to OP and pyrethroid insecticides. Some GPA populations are highly resistant to many insecticides. High GPA populations will stunt carrot growth causing curled and distorted leaves. In addition, GPA is a vector of many plant virus diseases. Diazinon (Diazinon) and malathion (Malathion) are two OP insecticides that have been used for aphid control in the past. Currently, there are no highly efficacious insecticides registered for GPA control on carrots in California that can be used as alternatives to the OP insecticides. In order to prevent GPA damage, pyrethroid or carbamate insecticides would need to be applied early in the season at lower GPA densities.

Field sanitation is an important cultural practice for reducing the number of GPA in and around carrot fields. GPA is attacked by a number of common predators and parasites and is susceptible to fungus diseases. Common predators include green lacewing, lady beetles and syrphid fly larvae. However, buildup of predators, parasites or pathogens rarely occurs prior to onset of economic damage.

Bean Aphid and Cotton/Melon Aphid

Bean Aphid (BA), *Aphis fabae*
Cotton/Melon Aphid (CA), *Aphis gossypii*

Little is known regarding BA damage to carrots. BA rarely causes economic damage to carrots and prefers sugar beets. No thresholds have been established for the treatment of BA on carrots. CA may occasionally cause injury that is similar to GPA damage. If populations are large enough, sooty mold may be produced. CA also is known to transmit more than 50 viruses, some of which affect carrots.

Prior to the mid-1990's, carrots planted adjacent to infested cotton or melon fields were at risk of becoming infested with CA, particularly in fall following cotton defoliation or termination of the melon crop. CA pest was prevalent on melons in the desert lower until pre-plant treatments with imidacloprid (Admire) were implemented for whitefly control. The CA populations were significantly reduced by Admire treatments, thus CA is rarely found on carrots.

Crown and Root Aphids

There are several species of aphids that attack the crown and roots of carrots. These include hawthorn aphid, parsley aphid, tulip bulb aphid and hawthorn carrot aphid. These aphids form colonies near the top of the root, at the base of the stems and occasionally form colonies on the root slightly below ground surface. All are similar in appearance with the wingless forms being pale yellow to gray green in color and covered with a powdery wax. Ants may attend all three aphid species. The presence of ants around the base of the plants indicates the presence of these aphids.

Crown and root aphid colonies are strongly clumped in a few small pockets in carrot fields and infrequently cause economically important injury. High crown and root aphid populations will stunt carrot growth but, more seriously, aphid feeding weakens the carrot top. The carrot tops break off during harvest, leaving the carrot in the ground. Imperial Valley carrot fields have occasionally been abandoned due to numerous crown and root aphid colonies that reduce the ability to mechanically harvest the carrots.

It is difficult to penetrate the carrot crop canopy to saturate the crown with insecticides and nearly impossible to treat the roots of the carrot crop with a post-emergence foliar spray. Since non-OP insecticides currently registered for use on carrots in California are not systemic, they have limited utility in treating the crown and root aphids. Sanitation and crop rotation to non-host crops are important cultural control methods to reduce the build-up of these aphids. Because these aphids feed near and below the soil line, predators and parasites are ineffective as control agents. In addition, ants that discourage the activity of predators and parasites attend the aphids.

Palestriped Flea Beetle (FB), *Systena blanda*

Adult flea beetle damage carrots by feeding on the undersides of leaves, leaving small pits or irregularly shaped holes on the leaves. Large populations can kill or stunt seedlings. Older plants rarely suffer economic damage although their older leaves may be damaged. FB larvae feeding on roots have caused serious damage on occasion in the Imperial Valley. This damage is easily confused with cavity spot symptoms. Cultural controls consist of removing weeds along field margins, deeply disc plant residue in infested fields after harvest and not planting into fields recently taken out of alfalfa or planting near alfalfa fields that are heavily infested with FB. Low FB populations can cause economic damage when plants are in the cotyledon stages and treatments may be required to develop a uniform stand. Once plants have several true leaves, they can tolerate several beetles per plant without damage. Older plants are even more tolerant. Insecticide treatments are rarely required. Esfenvalerate (Asana) has been sprayed for FB control. There are no other non-OP pre-plant insecticides registered in California for FB control.

Lepidopterous Pests

Several species of lepidopteran pests can be found in carrots, but populations of lepidopteran larvae rarely increase to damaging levels. When carrots are infested with damaging levels of a worm pest, OP insecticides are not usually used for their control. Many predator and parasite natural enemies attack worm pests. *Trichogramma* spp. wasp parasitize the eggs of many lepidopteran pests. Collops beetles, lacewing larvae, bigeyed bugs, damsel bugs, assassin bugs and spiders all attack small lepidoptera larvae. Among the most common parasites attacking beet armyworms are the wasps, *Hyposoter exiguae* and *Chelonus insularis*, and the tachnid fly, *Lespesia archippivora*. Viral diseases also kill significant numbers. These predators, parasites and disease organisms that attack worm pests rarely are abundant enough in carrots early in the growing season to prevent worm infestations.

Beet Armyworm (BAW), *Spodoptera exigua*

Beet armyworms feed in the crown of the plant and can severely stunt or kill seedlings, but rarely require treatment in established carrot stands. Treatment thresholds have not been established for BAW control in carrots. Seedling carrots may be treated if young larvae are present at plant emegerence.

Cutworms

Granulate Cutworm (GC), *Agrotis subterranea*
Variegated Cutworm (VC), *Peridroma saucia*

Several cutworm species can infest carrots but the two most common species are GC and VC. GC feeds largely underground, cutting plants off below the soil surface. Frequently, many plants in a row will be cut off during the night; often this is the first indication of a problem. GC is frequently a pest of carrots grown near alfalfa fields in the lower desert. On occasion GC migrates out of the alfalfa fields into carrots where it can consume young plants or clip them off below the ground as they feed. VC is a climbing species that feed above ground. Most feeding activity is nocturnal but they may frequently be found feeding during the day. VC also climbs on to older plants and feed mostly on young foliage in the center of the crown. They generally cause only minor damage. No economic thresholds have been established for cutworms. Cutworms often build up in crops preceding carrots, such as alfalfa. If cutworms are present in substantial numbers in the previous crops, carrots should not be planted. Spring plowing and discing is also useful in reducing cutworm numbers. Fields should be kept weed-free, particularly grassy weeds that serve as alternate hosts for cutworms.

Saltmarsh Caterpillar (SC), *Estigmene acrea*

The saltmarsh caterpillar is an occasional pest of carrot foliage in the southern San Joaquin Valley and lower desert. They are primarily a problem in fall when neighboring cotton fields are defoliated or alfalfa fields are harvested and the larvae migrate to young carrot fields. Migrating SC can be controlled culturally by making a ditch or trench around the edges of fields that border infested cotton or alfalfa fields. Treatment may be required if large numbers of SC migrate into carrot fields.

Whiteflies

Greenhouse Whitefly (GW), *Trialeurodes vaporariorum*
Sweetpotato Whitefly (SPW), *Bemisia tabaci*
Silverleaf Whitefly (SW), *Bemisia Argentifloii*

There are several species of whitefly that attack carrots including greenhouse whitefly, sweetpotato whitefly and silverleaf whitefly. In the lower desert, high populations of SW adults immigrate into seedling carrot fields during September and October, but rarely damage seedlings. In light to moderate infestations, leaves show no distinctive symptoms as a result of whitefly feeding. Heavy populations can deposit copious quantities of honeydew on leaves, resulting in a shiny, sticky appearance. Carrots are not a preferred host of whiteflies and treatment with insecticides is rarely justified. Occasionally, dense colonies of whitefly nymphs can require treatment to prevent honeydew and sooty molds from severely contaminating the carrot tops. Several parasitic wasps, including species in the *Encarsia* and *Eretmocerus* genera, are important in whitefly control. Common predators such as bigeyed bugs, lacewing larvae and lady beetles, also prey upon whitefly nymphs. Although the lady beetles, *Delphastus pusillus* and *Serangium parcesetosum*, along with several exotic species of whitefly parasites have been introduced into lower desert region to assist in biological control, the impact of these releases have yet to be determined. Encouraging buildup of beneficial insects by avoiding the use of harsh chemicals, removing field bindweed and other weeds in and adjacent to the carrot fields and establishing host free periods are all valuable methods for control of whiteflies.

Current Pest Management Program

Coast Region

The coast counties (Alameda, Contra Costa, Del Norte, Humboldt, Lake, Marin, Mendocino, Monterey, Napa, San Benito, San Mateo, Santa Clara, Santa Cruz, Sonoma, Los Angeles, Orange, San Diego, San Luis Obispo, Santa Barbara and Ventura) of California produce nearly 19,000 acres of carrots. Nearly a third of the carrots were treated with an insecticide in 1999 and about 14% were treated with the OP insecticides Diazinon or Malathion (Table 1). Diazinon or Malathion is typically applied for aphid control. In addition, Asana was applied to about 11% for flea beetle and other seedling pests. The average insecticide (material) cost per acre for carrot production in the coast region in 1999 was about is $3.50.

Southern San Joaquin Valley

The southern San Joaquin Valley is the largest carrot production region with approximately 45,000 acres and includes Fresno, Kern, Kings, Madera and Tulare counties. Only about 13% of the southern San Joaquin Valley carrots were treated with an insecticide in 1999 and less than 3% of the acreage was treated with an OP insecticide (Table 2). Asana or cyfluthrin (Baythroid) or methomyl (Lannate) were applied during stand establishment for control of crickets, earwigs, FB and cutworms. The average insecticide (material) cost per acre for carrot production in the southern San Joaquin Valley in 1999 was about $1.50.

Lower Desert Region

The lower desert region is the second largest carrot production area with approximately 29,000 acres and includes Imperial, Inyo, Riverside and San Bernardino counties. In 1999, nearly 85% of the carrot acreage was treated with an insecticide and about 35% was treated with the OP insecticides Diazinon or Malathion (Table 3). Diazinon or Malathion was applied for stand establishment or for aphid control later in the season. Asana, Baythroid and Lannate were applied early in the season at stand establishment for control of crickets, earwigs, FB and cutworms. These insecticides can also be used for foliar pests during the growing season. The average insecticide (material) cost per acre for carrot production in the lower desert region in 1999 was about $7.00.

OP Free – Pest Management Program with Available Technology

The OP free programs described below were constructed with currently registered insecticides for immediate implementation without regard to secondary pest outbreaks or insecticide resistance management consequences. It is anticipated that there will be no significant yield decrease over current levels with the elimination of the OP insecticides.

Coast Region

In the coast region, growers would rely primarily on Asana and Lannate for insect control in an OP free pest management program using currently registered insecticides. There would be a slight increase in the number of applications due to the elimination of Diazinon and Malathion for aphid control (Table 4). Control of aphids would be difficult without Diazinon and would require more frequent applications of endosulfan (Thiodan) and Asana. Using increased amounts of pyrethroid insecticides could potentially lead to spider mite problems, but this is unlikely due the low percentage of carrot acreage that needs to be treated. Alternative insecticides to the pyrethroids for aphid control would be Thiodan or insecticidal soap (M-Pede) if spider mites become a problem. GPA resistance to several classes of insecticides is well known, but the limited use of insecticides would have a minimal impact on the development of insecticide resistance. Asana, Thiodan and Lannate could be used to control seeding pests such as crickets, earwigs, FB and cutworms. The average insecticide cost per acre for the coast region should not significantly change in an OP free pest management program with currently registered insecticides.

Southern San Joaquin Valley

In the southern San Joaquin Valley, there would be no or very little change in the insecticide use patterns since few or no OP insecticide applications are used on carrots (Table 5). The principle problem is seedling pests. Asana, Baythroid, Lannate or Thiodan would be used to control seedling pests early in the season for stand establishment. Aphids are not a significant pest in southern San Joaquin Valley. The average insecticide cost for the southern San Joaquin valley should not significantly change in an OP free pest management program.

Lower Desert Region

In the lower desert region, growers would rely primarily on Asana, Baythroid, Thiodan and Lannate for insect control in an OP free pest management program. There would be a slight increase in the number of applications due to the elimination of Diazinon and Malathion for aphid control (Table 6). Control of aphids would be difficult without Diazinon and control would require more frequent applications of the Thiodan and Asana. Control of FB and other seeding pests would rely on Asana and Lannate. The average insecticide cost per acre for the lower desert region should change little with an OP free pest management program with currently registered insecticides.

OP Free – Pest Management Program with Emerging Technology

The pest management programs below were constructed with currently registered insecticides and/or insecticides that are anticipated to be registered within four to five years. Pest management programs would require a greater reliance on cultural and biological alternatives and would produce a more stable long-term program that would allow for much greater impact of beneficial insects on the pest populations.

Coast Region

In the coast region, growers would rely on imidaclorprid (Provado) for aphid control, spinosad (Success) or tebufenozide (Confirm) for lepidopterous larval control and Asana or Thiodan for seedling pest control (Table 7). This pest management program would produce a relatively stable long-term program that would allow for a much greater impact of beneficial insects on the pest populations with the exception of the Asana or Thiodan application. There are no new insecticides near registration that will control seedling pests in as rapid a manner as Asana or Thiodan. The rapid control of Asana and Thiodan would be needed for stand establishment but would only be applied to a small acreage. It is anticipated that Asana or Thiodan would be applied to only about 2.5% of the carrot acreage in the coast region. Provado would provide excellent aphid control and it is anticipated that Provado would be applied to about 25% of the acreage. Success or Confirm would provide excellent lepidopterous larval control and it is anticipated that Success or Confirm would be applied to about 2.5% of the acreage.

Southern San Joaquin Valley

In the southern San Joaquin Valley, seedling pests are the major concern of growers while aphids do not pose a significant problem. Asana and Thiodan would be used to control seedling pests. It is anticipated that Asana or Thiodan would be applied to about 10% of the carrot acreage in the San Joaquin Valley (Table 8). Lepidopterous larvae can be pests of both seedling carrots and carrots as the season progresses. Lepidopterous larvae would be controlled with Success or Confirm and it is anticipated that Success or Confirm would be applied to about 5% of the acreage. Aphids which are not a major pest of carrots in the southern San Joaquin Valley would be controlled with Provado. Provado would be applied to about 2.5% of the acreage.

Lower Desert Region

In the lower desert region, growers would rely on Provado for aphid control, Success or Confirm for lepidopterous larval control and Asana or Thiodan for seedling pest control (Table 9). Pest management is more difficult in the lower desert than the other two growing areas. There would be a greater reliance on Asana and Thiodan for stand establishment and a greater use of Success or Confirm for BAW and cutworm control both during the seedling stage and as the season progresses. It is anticipated that Asana or Thiodan would be applied to about 10% of the carrot acreage in the lower desert region. Provado would provide excellent aphid control and it is anticipated that Provado would be applied to about 20% of the acreage while Success or Confirm would provide excellent lepidopterous larval control. It is anticipated that Success or Confirm would be applied to about 10% of the acreage.

Table 1. Insecticide and Miticide Use on Carrots in the Coast Regions of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
cyfluthrin (Baythroid)	47	1,068	5.8	$13,558
diazinon (Diazinon)	1,641	1,540	8.3	$15,160
esfenvalerate (Asana)	100	2,053	11.1	$18,164
malathion (Malathion)	1,848	1,047	5.6	$10,108
methomyl (Lannate)	175	242	1.3	$3,893

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the Coast Regions is about $3.28.

Table 2. Insecticide and Miticide Use on Carrots in the Southern San Joaquin Valley of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
cyfluthrin (Baythroid)	17	444	0.9	$4,985
diazinon (Diazinon)	1,198	240	0.5	$11,069
Esfenvalerate (Asana)	183	4,009	8.5	$33,302
Malathion (Malathion)	1,894	984	2.1	$10,361
Methomyl (Lannate)	416	470	1	$9,243

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the Southern San Joaquin Valley is about $1.46.

Table 3. Insecticide and Miticide Use on Carrots in the Desert Regions of CA, 1999

Material*	**Lb (ai)**	**Acres Treated**	**% Acres Treated**	**Costs**
clarified neem oil (Triology)	1,925	1,203	4.1	$3,851
cyfluthrin (Baythroid)	169	4,502	15.3	$48,908
diazinon (Diazinon)	4,102	8,346	28.4	$37,904
esfenvalerate (Asana)	260	6,404	21.8	$47,197
malathion (Malathion)	2,405	1,755	6	$13,153
methomyl (Lannate)	2,315	3,739	12.7	$51,435

*Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the Desert Regions is about $6.90

Table 4. Insecticide Use in an OP free Pest Management Program with Available Technology on Carrots in the Coast Region

Material	**Rate Form/ac**	**# Appl./ Season**	**Pest**	**Notes**
esfenvalerate (Asana XL)	1/2 pt	1/5	Lepidopterous larvae, Aphids, FB and Seedling pests	May disrupt biological control
or				
cyfluthrin (Baythroid 2)	1/2 pt			
endosulfan (Thiodan 3EC)	1/2 pt	1/40	Lepidopterous larvae, Aphids, FB, and Seedling pests	
methomyl (Lannate SP)	1 lb	1/10	Lepidopterous larvae, FB and Seedling pests	May disrupt biological control

Table 5. Insecticide Use in an OP free Pest Management Program with Available Technology on Carrots in the Southern San Joaquin Valley

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
esfenvalerate (Asana XL)	1/2 pt	1/10	Lepidopterous larvae, Aphids, FB, and Seedling pests	May disrupt biological control
or				
cyfluthrin (Baythroid 2)	1/2 pt			
endosulfan (Thiodan 3EC)	1/2 pt	1/40	Lepidopterous larvae, Aphids, FB, and Seedling pests	
methomyl (Lannate SP)	1 lb	1/40	Lepidopterous larvae, FB, and Seedling pests	May disrupt biological control

Table 6. Insecticide Use in an OP free Pest Management Program with Available Technology on Carrots in the Lower Desert Region

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
esfenvalerate biological (Asana XL)	1/2 pt	1/2	Lepidopterous larvae, Aphids, FB and Seedling pests	May disrupt control
or				
cyfluthrin (Baythroid 2)	1/2 pt			
endosulfan (Thiodan 3EC)	1/2 pt	1/20	Lepidopterous larvae, Aphids, FB and Seedling pests	
methomyl (Lannate SP)	1 lb	1/10	Lepidopterous larvae, FB, and Seedling pests	May disrupt biological control

Table 7. Insecticide Use in an OP free Pest Management Program with Emerging Technology on Carrots in the Coast Region

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
imidacloprid (Provado 1.6F)	1/4 pt	1/4	Aphids	Not registered
spinosad (Success 2SC)	1/2 pt	1/40	Lepidopterous larvae	Not registered
or				
tebufenozide (Confirm 2F)	1/2 pt			Not registered
esfenvalerate (Asana XL)	1/2 pt	1/40	Seedling pests	May disrupt biological control
or				
endosulfan (Thiodan 3EC)	1/2 pt			

Table 8. Insecticide Use in an OP free Pest Management Program with Emerging Technology on Carrots in the Southern San Joaquin Valley

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
imidacloprid (Provado1.6F)	1/4 pt	1/40	Aphids	Not registered
spinosad (Success 2SC)	1/2 pt	1/20	Lepidopterous larvae	Not registered
or				
tebufenozide (Confirm 2F)	1/2 pt			Not registered
esfenvalerate (Asana XL)	1/2 pt	1/10	Seedling pests	May disrupt biological control
or				
endosulfan (Thiodan 3EC)	1/2 pt			

Table 9. Insecticide Use in an OP free Pest Management Program with Emerging Technology on Carrots in the Lower Desert Region

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
imidacloprid (Provado1.6F)	1/4 pt	1/5	Aphids	Not registered
spinosad (Success 2SC)	1/2 pt	1/10	Lepidopterous larvae	Not registered
or				
tebufenozide (Confirm 2F)	1/2 pt			Not registered
esfenvalerate (Asana XL)	1/2 pt	1/10	Seedling pests	May disrupt biological control
or				
endosulfan (Thiodan 3EC)	1/2 pt			

COTTON

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Cotton is produced on over a million acres of California. The majority of the production is concentrated in the San Joaquin Valley with some production also occurring in the lower deserts and Sacramento Valley. California growers produce both upland (*Gossypium hirstum*) and Pima (*G. barbedense*) cotton species averaging 2 1/4 bales of cotton lint per acre. High productivity in California can be attributed to irrigation and an extended growing season. Many insects and mites can be found in cotton, however only a few are pests. The insect pests against which chemical treatment was required were lygus bugs (62%), spider mites (31%), aphids (4%) and leaf-feeding lepidopterous larvae (3%), including beet armyworm and cabbage looper. Pink bollworm and silverleaf whitefly are important pests in the lower desert while silverleaf whitefly is potentially a pest of southern San Joaquin Valley. Most of these pests do not prefer cotton and dispensers to cotton from their primary host. This makes monitoring and sampling in all adjacent fields and weeds vital to the development of an appropriate insect pest management plan. For example, cotton planted near alfalfa or safflower fields may experience persistent dispersal from lygus bugs and lepidopterous pests from these host crops.

Lygus Bugs (LB)

Lygus hesperus
Lygus elisus

Lygus bugs are a common pest on several crops throughout the western United States. While different species of LB may occur, *Lygus hesperus* is the most common species, and regularly damages cotton in the San Joaquin Valley. Since cotton is not the preferred host for LB, they often migrate from adjacent fields of alfalfa, safflower and other field crops. Drying of safflower fields for harvest, cutting of alfalfa fields and drying or disking of weeds often force adults to migrate into adjacent cotton fields. Unfortunately, many times this period coincides when cotton plants are most vulnerable to LB attack, i.e. May through early July.

Female LB deposit cylindrical eggs in plant tissue, usually in the petiole joining the leaf blade. LB attacks young developing flower buds (square) and young fruit (bolls), causing square and bolls to drop. The early fruiting period is most vulnerable and early fruit loss may keep the plant in a vegetative growth phase. The condition of the cotton field, stage of fruit development and availability of different hosts all contribute to the potential LB population level in cotton fields. LB treatments are triggered when bug densities cause damage exceeding the expected shed rates.

There are no selective or reduced risk insecticides that are effective against LB. Organophosphate (OP) insecticides have been the first choice for LB control. However, OP insecticides have become less effective over the years. They also are broad-spectrum that can lead to a reduction of beneficials. Pyrethroid insecticides appear to give the longest residual control. However both classes of pesticides are non-selective and can cause secondary outbreaks of aphids, spider mites and worms. Aldicarb (Temik) is the most widely used carbamate insecticide, but must be applied prophylactically before LB problems develop. Oxamyl (Vydate) is another carbamate often used. Typical pyrethroids used for LB control include bifenthrin (Capture), cyfluthrin (Baythroid), cypermethrin (Ammo), fenproathrin (Danitol) and lamba-cyhalothrin (Warrior). However, these chemicals are also applied for control of worm pests and whiteflies. Imidacloprid (Provado) and thiamethaoxam (Actara) are less disruptive than other alternatives, but only suppresses populations often not achieving adequate control.

Cotton/Melon Aphid (CA), *Aphis gossypi*

Cotton aphid has been minor pest with cotton as long as cotton has been produced in California. CA occasionally infest early season (pre-squaring) or late season (exposed lint) cotton. However during the 1990's it shifted into the mid-season period threatening yield and quality. Winged adults usually migrate, or are blown by wind, from neighboring hosts into seedling cotton fields in May and June. Recently, winged aphids have recolonized cotton fields during the mid-season of June through August. The cause of this shift is unknown, but several theories exist: (1) a shift in insecticide classes from OP to pyrethroid insecticides, (2) a shift in management tactics to encourage vigorous early growth, (3) a shift in the cropping landscape from row crops to increased permanent crops and (4) changes in varieties and species of cotton grown.

Aphids can cause the leaves of seedlings to "cup," experience slow growth, and produce excess honeydew on which sooty mold develops. During the mid-season, heavy aphid populations may stress plants leading to stunted growth and reduced yield from increased square and boll shedding. Late in the season honeydew contaminates exposed cotton lint. Lady beetles, syrphid flies, parasitic wasps, pirate bugs, a number of common arthropod predators and *Entomophthora* fungus are important components of aphid control. However, while these natural enemies may help to suppress aphid populations, they may not achieve adequate control to prevent economic damage. Management of CA has depended on OP insecticides. CA in the San Joaquin Valley has exhibited resistance to OP, pyrethroid and carbamate insecticides. Provado and Actara are effective against CA early in the season while Temik has also been widely used for CA control. Beside Temik, endosulfan (Thiodan) is a non OP insecticide alternative.

Spider Mites

Strawberry Spider Mite (SSM), *Tetranychus turkestani*
Pacific Spider Mite (PSM), *Tetranychus pacificus*
Twospotted Spider Mite (TSSM), *Tetranychus urticae*
Carmine Spider Mite (CSM), *Tetranychus cinnabarinus*

A variety of spider mites may infest cotton fields. The strawberry, Pacific, twospotted and carmine spider mites tend to be the most common. SSM are typically the first species present in cotton fields followed later by populations of PSM and TSSM. In warm weather a generation can take as little as five days with an average near ten generations a year in cotton. Adults are often blown into cotton fields by wind from adjacent crops such as alfalfa. Dusty roads conditions adjacent to field borders can contribute to spider mite problems. Spider mites are annual pests, but severity of infestation can be attributed to insecticide patterns, predator abundance and weather. Mites feed on foliage causing leaves to turn yellow or red and may reduce yield. Control of spider mites relies on a number of selective miticides including avermectin (Zephyr), dicofol (Kelthane) and propargite (Comite). However, populations of TSSM and PSM have shown resistance to these and other frequently used insecticides. Thus, resistance management through product rotation is key in maintaining a susceptible population. OP and carbamate insecticides are not recommended for use against spider mites. OP and carbamate insecticides eliminate the beneficial insect and mite complex which may result in spider mite flare-ups.

Whiteflies

Greenhouse Whitefly (GW), *Trialeurodes vaporariorum*
Silverleaf Whitefly (SLW), *Bemisia Argentifloii*
Sweetpotato Whitefly (SW), *Bemisia tabaci*

The greenhouse whitefly, sweetpotato whitefly and the silverleaf whitefly are the most common whitefly pests. In the southern San Joaquin Valley, GW was once the predominant species and in the lower desert valleys, SW was once the predominant species. However, SLW has replaced GW and SW and is now the predominate species. SLW can cause significant economic losses. Found mostly on the underside of leaves, whiteflies have a diverse host range and often migrate from adjacent fields into cotton. Eggs are laid on the bottom side of leaves and take a few days to hatch. Larvae progress through four instars with a complete generation of SLW being completed in less than 20 days during the summer. The larvae feed by extracting fluid from leaves, often excreting excess honeydew, which can damage exposed lint. Heavily infested plants may become blackened due to development of sooty mold on honeydew. SLW is also a potential vector of many viruses that can affect several crops, including leaf crumple in cotton. The key to preventing outbreaks of whitefly populations is to conserve beneficial insects, especially parasitic wasps (e.g. *Eretmocerus haldemani*) which can contribute to as much as 70% to 90% control. Infestation early in the growing season are controlled with an insect growth regulator (IGR) insecticide, pyriproxyfen (Knack) or buprofezin (Applaud) while late infestations are often treated with pyrethroid and OP insecticides, but control with insecticides can be difficult. A majority of the population will consist of eggs and larvae under leaves that are difficult to reach with conventional insecticide applications. Treatment thresholds are based on presence/absence inspections on leaves. Resistance has been documented and must be taken into account prior to selecting appropriate management options.

Lepidopterous Pests

Cotton Bollworm (CBW), *Helicoverpa zea*
Tobacco Budworm (TBW), *Helicoverpa virescens*
Pink Bollworm (PBW), *Pectinophora gossypiella*
Beet Armyworm (BAW), *Spodoptera exigua*
Yellowstriped Armyworm (YAW), *Spodoptera praefica*
Cabbage Looper (CL), *Trichoplusia ni*
Saltmarsh Caterpillar (SC), *Estigmene acrea*

A number of lepidopterous larvae can infest cotton and result in serious economic losses if not controlled. The most economically important lepidopterous pests are CBW, TBW and PBW. These pests damage fruit structures (squares and bolls) and can cause direct yield loss. CBW is a pest throughout the state while PBW and TWB are confined to the lower desert regions. In addition, later instars of BAW have also been observed to damage squares and bolls during mid-season. However, BAW feeds primarily on the foliage. There is a number of foliage feeding lepidopterous larvae that include BAW, YAW, CL and SC. Cotton is not a preferred host of many of these pests so infestations are generally determined by the characteristics of adjacent fields, weeds and crops. Natural predators are the key to keeping lepidopterous larval populations below an economic threshold. In some cases, a moderate population of CL and AL will actually benefit pest management by providing a reservoir for natural enemies while only causing minimal damage to foliage. Unfortunately, insecticide applications for other insect pests, particularly for LB, destroy predators and parasites and create conditions for outbreaks of lepidopterous larval pests.

Control of foliage feeding lepidopterous larvae has relied primarily on OP and carbamate insecticides in the past. However, there are a number of highly effective reduced risk insecticides available for control of SC, CL, YAW and to some extent BAW. These insecticides include new *Bacillus thuringiensis* (Bt) formulations, spinosad (Success), tebufenozide (Confirm) and indoxacarb (Steward). BAW, TBW and CBW can be difficult to control and may require several applications of an OP, carbamate and pyrethroid insecticide when populations are high. Control of PBW relies on mating disruption using gossyplure (Nomate PBW) and early crop termination in addition to OP or pyrethroid insecticides. The use of Nomate PBW has been significantly reduced because of the cost of the material and the reliance on transgenic Bt cotton. Bt cotton now composes 80% of the cotton planted in the California lower desert valleys. As a result, TBW and PBW populations are now controlled in large measures by Bt transgenic cotton. However, it should be noted that transgenic Bt cotton is not equally effective against all lepidopterous larval pests. BAW is more resistant to transgenic Bt cotton than other lepidopterous pests.

Current Pest Management Program

Central Valley

The Central Valley includes Butte, Colusa, Glenn, Placer, Sacramento, Solano, Sutter, Tehama, Yolo, Yuba, Merced, San Joaquin, Stanislaus, Fresno, Kern, Kings, Madera and Tulare counties. The primary pests of cotton in the Central Valley are LB, spider mites, CA, whiteflies and to a lesser extend lepidopterous larvae. Central Valley cotton received on average 1 and 1/2 insecticide or miticide applications during 1999 (Table 1). About 1/2 an application was an OP insecticide, about 1/2 application was a miticide and about 1/3 of an application was a carbamate insecticide. A small amount of the acreage (14%) was treated with a pyrethroid or other class of insecticide. There are three distinct cotton-growing regions within the Central Valley (Sacramento, northern and southern San Joaquin valleys). The insect pest complex and severity of infestation varies between the three region with the southern San Joaquin Valley has the most server insect and mite infestations. In the Sacramento Valley, the primary insect pests are LB, CA and lepidopterous larvae. In the northern San Joaquin Valley, lygus bugs are less of a problem while spider mites are the major pest. In the southern San Joaquin Valley, lygus bugs, spider mites, aphids, whiteflies and lepidopterous pests are all pests depending on the years and choice of insecticides. The choice of insecticide has a direct influence on the potential for secondary pest outbreaks. Use of broad-spectrum OP, pyrethroid and carbamate products has contributed to outbreaks of mites, aphids, whiteflies and lepidopterous larvae. These outbreaks are the result of the elimination of beneficial insects and mites and the development of resistance by the pest species.

Spider mites are the first pests to develop damaging levels that require a miticide application. In 1999, over 32% of the cotton growing acreage of the Central Valley was treated with Zephyr for control of spider mites (Table 1). In addition, Kelthane was used on over 16% of cotton fields while Comite was applied to 3% of the Central Valley acreage for spider mite control. Some populations of spider mites have developed resistance to Kelthane while Comite maybe phytotoxic to young plants under 10 inches in height. Thus Zephyr is being used on a large percentage of the acreage.

Temik is applied at-planting to suppress spider mites and thrips or Temik can be side-dressed for later in the season for LB and CA control. Temik was applied to over 21% of the cotton growing acres in the Central Valley. Other products used for LB control are the pyrethroids e.g. Capture, Baythroid, Ammo and Warrior. The pyrethroids are applied to nearly 14% of the acreage. Majority of these applications occurred in the southern San Joaquin Valley. Naled (Dibrom) and Vydate was applied to about 15% and 9%, respectively, of the cotton acreage for LB control. These insecticides can be rotated with Orthene and methamidophos (Monitor) to help avoid resistance problems. Orthene, Dibrom and Monitor are also used for control of CA and lepidopterous pests and was applied to about 2% of the acreage.

Some fields in the southern San Joaquin Valley experience continual problems with early season CA. In addition, CA populations are known to have developed resistance to all of the most commonly used insecticides. Control of CA in the Central Valley has relied on mainly on OP insecticides. Chlorpyrifos (Lorsban), the most widely used cotton insecticide, was applied to nearly 27% of the acreage in the Central Valley. Lorsban can control aphids as well as LB and whiteflies. Carbofuran (Furadan) used typically late in the season for CA control was applied to about 4% of the acreage. Cotton growers in the Central Valley applied Provado to nearly 5% of the total acres.

Whitefly can be a problem in some years in the southern portion of the Central Valley. Often associated with melons and cole crops, most severe infestations occur late into the summer months. Treatment for whiteflies includes the previously mentioned insecticides, such as Lorsban and Vydate, as well as Capture. Lepidopterous pests such as CBW and BAW may occasionally require treatment. Thiodicarb (Larvin) is used to control CBW and BAW, along with other worm pests, and was applied to over 5% of the total cotton growing acres in the Central Valley. Treatments of Lorsban, Monitor or Orthene for other pests also suppress worm populations.

Lower Deserts

The lower desert includes Imperial and eastern Riverside counties. The primary pests of cotton in the lower desert are whiteflies, PBW, TBW and to a lessor extent LB. Lower desert cotton received on average 3 and 1/4 insecticide or miticide applications during 1999 (Table 2). About 1 1/2 applications were an OP insecticide, about 1 application was a pyrethroid and about a 1/3 of an application was a carbamate insecticide. A small amount of the acreage (18%) was treated with a miticide or other class of insecticide. The major insect pest was whiteflies. Control of whiteflies relied primarily on Orthene and pyrethroid (Danitol, Capture, Baythroid, Ammo and Warrior) insecticides. Orthene was applied about 1.2 times and account for the majority of OP use. In addition, Temik was applied for whitefly control to about 28% while Vydate was applied to about 9% of the acreage. These insecticides also suppress LB, PBW and TBW populations. Control of PBW and TBW was controlled in large measure by Bt transgenic cotton. In addition to Bt transgenic cotton and the above pyrethroid insecticides, control of PBW and TBW along with other worm pests, relied on Larvin and Lorsban. Spider mites are not a significant problem in the lower deserts and only 15% of the acreage was treated with a miticide.

OP Free-Pest Management with Available Technology

The OP free programs below were constructed with currently registered insecticides and miticides for immediate implementation and without regard to resistance management consequences.

Central Valley

A pest management program in cotton, without OP insecticides, would rely on a number of miticides (Zephyr, Kelthane and Comite), pyrethroid insecticides (Capture, Baythroid, Warrior and others), neonicotinoid insecticides (Provado and Actara), carbamate insecticides (Thiodan, Temik and Lannate), IGR insecticides (Applaud, Knack and Confirm) and a number of reduced risk insecticides (Bt, Success and Steward) (Tables 3 & 4). The pyrethroid would be used to control LB while CA control would rely on Provado, Actara and Thiodan. Additional control of both LB and CA would rely on Temik. The loss of the OP insecticide would not have a great impact on miticide use and miticide use should largely be unchanged from present conditions. However the loss of OP insecticides would have the greatest influence on aphid management. Since pyrethroid insecticides would be the primary OP insecticide substitute for LB control and since pyrethroid insecticides have been implicated in aphid outbreaks through the destruction of natural enemies as well as a direct effect on aphid life cycle, Provado and Actara use would increase for management of CA. However, Provado and Actara need to be applied early when the CA population is low. Extensive outbreaks of CA would not be managed with Provado and Actara alone and additional control would be provided by Thiodan. However, Thiodan would provide only minimal CA control and increased resistance to Thiodan in CA would be anticipated. Given the potential difficulty of controlling CA with Thiodan and Provado, a prophylactic application of Temik would be applied to most acreage. Temik and to a lesser extent Provado and Actara would also provide control of LB. Temik is a systemic carbamate insecticide that is taken up by the plant from the soil. Since Temik is applied to the soil, it would have minimum effects on wildlife and worker safety. Beneficial insects are not directly eliminated by the application of Temik as they are with OP or pyrethroid insecticides. However, if predatory insects such as big-eyed, damsel, assassin or minute pirate bug feed on plant fluid, they will be killed by the Temik application. These true bugs and other beneficial insects help control the lepidopterous larval pests and increased infestations of lepidopterous larvae have been observed following Temik applications. Control of lepidopterous larvae, particularly BAW, would rely on reduced risk insecticides such as Steward, Success, Confirm and Bt and would not be greatly affected by the elimination of OP insecticides since OP insecticides are not used to any great extent of lepidopterous larval control. Control of whitefly, particularly in the southern San Joaquin Valley, would rely on recently registered IGR insecticides such as Applaud and Knack as well as Capture. Whiteflies are much less of a problem in the Central Valley as compared to the lower deserts.

Lower Deserts

A pest management program in cotton without OP insecticides would rely primarily on a number of miticides (Kelthane and Comite), pyrethroid insecticides (Capture and Baythroid), carbamate insecticide (Temik), IGR insecticides (Applaud, Knack and Confirm) and a number of reduced risk insecticides (Bt, Success and Steward) (Tables 5 & 6). The primary pests of cotton in the lower desert are whiteflies. Control of whiteflies would rely primarily on the IGR insecticides Knack and Applaud and to a lesser extent on pyrethroid insecticides (Danitol or Capture). Danitol and Capture also suppress LB, PBW and TBW populations. Control of LB would rely on a Temik side-dress application. This application would also assist in the suppression of spider mites. However, spider mites are not a significant problem in the lower deserts. If spider mites become a problem then an application of Kelthane or Comite would suppress the spider mite population. Control of PBW and TBW would in large measure by Bt transgenic cotton. In addition to Bt transgenic cotton and the above pyrethroid insecticides used for whiteflies and LB control, control of PBW and TBW along with other worm pests, relied on Success, Confirm, Steward or Bt.

OP Free – Pest Management Program with Emerging Technology

The pest management programs below were constructed with currently registered insecticides and/or insecticides or control methods that are anticipated to be registered within four to five years. The pest management program with emerging technology would produce a stable long-term program that would allow for much greater impact of beneficial insects and mites on the pest populations. The pest management program would maintain low densities over time and prevent large pest density oscillations.

The OP free pest management program with emerging technology is very similar to the OP free pest management program with available technology. The major difference is the anticipated registration of Aphidstar for CA control, Envidor and Mesa for spider mite control and Demim and Intrepid for lepidopterous larval control.

Central Valley

The key to cotton insect pest management in the Central Valley is LB. However, no new technologies are on the horizon that provides selective, reduced risk control for LB. The neonicotinoids such as Provado or Actara suppress LB but do not provide adequate LB control as compare to pyrethroid or carbamate insecticides. If repeated applications of broad-spectrum pyrethroid or carbamate insecticides are applied for LB management, then secondary outbreaks of CA, spider mites and foliar-feeding worms would be expected. The use of Temik would significantly reduce the use of pyrethroid insecticides (Table 7). Temik is a highly toxic systemic carbamate insecticide. However, it is applied to the soil at planting and/or as a side-dress application to the young plants. The plants take up the Temik into the plant tissues. This application method prevents exposure to most beneficial insects and mites and avoids worker exposure. However, high rates of Temik have been associated with square (flower bud) drop. Also beneficial insects that feed on plant fluid will be killed by the Temik application. Thus Temik, Provado and Actara should control LB. However high populations of LB migrating from adjacent host plants will require the application of a pyrethroid insecticide to suppress these large populations. It is anticipated that a pyrethroid insecticide would be required on about 10 to 20% of the fields.

Control of CA would be difficult without OP insecticides. However, Provado and Actara are effective against developing populations early in the season. The use of Provado or Actara early in the season against low population of would provide adequate control. The addition of Actara registration this past summer would allow growers to select between the two materials. The registration of two competing materials should cause a reduction in the price to the growers. In addition to the neonicotinoid insecticides, triazamate (Aphidstar) and pymetrozine (Fulfill) are a highly effective new reduced risk insecticides that is expected to be registered on cotton within four to five years. Aphidstar and Fulfill can be used to reduce established CA populations. The use of the neonicotinoids, Aphidstar and Fulfill should allow for management of CA populations.

Control of spider mites would rely on Kelthane, Zephyr and two new selective miticides spirodicolfen (Envidor) and milbemectin (Mesa). Spider mites are controlled to a large extent by beneficial insects and mites. When these beneficials have been eliminated by the applications of OP or pyrethroid insecticides, spider mite populations can increase to damaging levels. However, the reduction in the usage of pyrethroid insecticides and the elimination of OP insecticides would allow for much greater beneficial insect and mite activity and a reduction in the spider mite populations and a reduction in the usage of miticides. In the 10-20% of the fields that require pyrethroid insecticides for control of LB, Spider mite pressure would occur primarily mid to late season. However, heavy population densities in late season will crate conditions for early season outbreaks the following year if the same fields are planted to cotton (winter population carryover). The mid to late season control will fall on Zephyr while early season might be able to use a single Kelthane application. Comite would be used mid to late season but coverage for any product after lay by is poor and control becomes problematic.

Control of whiteflies would rely on two recently registered reduced risk insecticides, Applaud and Knack. However, whiteflies are not significant problems in the northern San Joaquin and

Sacramento valleys. Whiteflies have become more of a problem in the southern San Joaquin Valley. With the elimination of the OP insecticides and reduction of the pyrethroid and carbamate insecticides, the beneficial insects, particularly Encarsia and Eretocerus spp., will have a greater impact on the whitefly population. It is anticipated that Applaud or Knack would be required on about 10% of the fields in the southern San Joaquin Valley.

Control of lepidopterous larvae would rely on currently available reduced risk insecticides, e.g.. Steward, Success and Confirm. There are two new reduced risk insecticides, emamectin benzoate (Demim) and methozyfenoxide (Intrepid) that are expected to be registered within two or three years. These materials will add greater choice and flexibility in pesticide selection.

Lower Deserts

The key to cotton insect pest management in the lower deserts is control of whiteflies and PBW. Control of whiteflies would rely on Applaud and Knack (Table 8). These two IGR insecticides have become the cornerstone of successful whitefly control program. The use of one, or both in succession, often gives effective season-long whitefly control without resorting to pyrethroid insecticides. Thresholds are well established for the first application of an IGR. The second application of the second IGR is less clearly delineated. With the elimination of the OP insecticides and reduction in the pyrethroid insecticides, the beneficial insects, particularly Encarsia and Eretocerus spp., will have a greater impact on the whitefly population.

The major lepidopteran pests of cotton in the lower deserts are PBW and TB. Control of PBW would rely on early crop termination and Bt transgenic cotton. Bt cotton would control in large measure the TB populations. However, if TB or BAW populations become a problem, then control would rely on currently available reduced risk insecticides, e.g.. Steward, Success and Confirm. There are two new reduced risk insecticides, Demim and Intrepid that are expected to be registered within two or three years. These materials will add greater choice and flexibility in pesticide selection.

Lygus bugs can be a significant problem when cotton is grown in close proximity to alfalfa hay. The LB develops in alfalfa hay and disperses to adjacent cotton fields. Cutting alfalfa hay in rotating pattern among several adjacent alfalfa hay fields can reduce lygus problems. However, rotation of cutting is not always possible. Control of lygus bugs would rely on an application of Temik and to a lesser extent Provado and Actara. However if high populations of LB are observed, then it is anticipated that a pyrethroid insecticide would be required on about 10 to 20% of the fields.

Cotton aphid is not a significant pest in the lower deserts. Since CA populations often do not develop into damaging populations, Provado or Actara would not be required in early season when the populations are very low. However, if CA populations increase to damaging levels later in the season then an Aphidstar application would suppress the populations below damaging levels.

Control of spider mites would rely on Zephyr and two new selective miticides Envidor and Mesa. Spider mites are not as significant a problem in the lower deserts as in the Central Valley.

Spider mites are controlled to a large extent by beneficial insects and mites. When these beneficials have been eliminated by the applications of OP or pyrethroid insecticides, spider mite populations can increase to damaging levels. However, the reduction in the usage of pyrethroid insecticides and the elimination of OP insecticides would allow for much greater beneficial insect and mite activity and a reduction in the spider mite populations and a reduction in the usage of miticides.

Addendum

A new insecticide, acetamiprid (Assail), has been registered in cotton since the economic analysis. Assail will be added to the existing arsenal of selective reduced risk lepidopteran insecticides, e.g., indoxacarb (Steward), spinosad (Success), tebufenozide (Confirm) and *Bacillus thuringiensis* (various products). Assail is a neonicotinoid insecticide that has lepidopteran activity as well as aphid activity. However, Assail provides little lygus bug control. Control of lygus bugs will continue to rely on aldicarb (Temik) and various pyrethroid insecticides. Assail will be useful when multiple pests, i.e., aphids and lepidopteran pests, are present simultaneously. However, this new product will not have a major impact on cotton IPM.

Table 1. Insecticide and Miticide Use on Cotton in the Central Valley of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
acephate	24,040	26,557	2.3	$480,793
Orthene				
aldicarb	257,928	249,452	21.4	$7,100,754
Temik				
amitraz	7,406	14,106	1.2	$170,332
Ovasyn				
abermectin	2,304	381,242	32.7	$11,538,232
Zephr				
bifenthrin	6,292	86,051	7.4	$1,321,255
Capture				
carbofuran	13,279	49,830	4.3	$279,926
Furadan				
chlorpyrifos	278,565	310,709	26.7	$5,270,446
Lorsban				
cyfluthrin	909	20,789	1.8	$263,659
Baythroid				
cypermethrin	812	13,440	1.2	$94,212
Ammo				
dicofol	219,769	194,922	16.7	$6,179,903
Kelthane				
dimethoate	38,985	86,463	7.4	$384,003
Dimethoate				
fenpropathrin	37	169	>0.1	$2,091
Danitol				
imidacloprid	2,455	53,123	4.6	$835,827
Provado				
lamba-cyhalothrin	1,029	35,839	3.1	$432,369
Warrior				
methamidophos	17,429	24,735	2.1	$411,836
Monitor				
naled	166,167	172,049	14.8	$1,739,765
Dibrom				
oxamyl	79,497	105,328	9	$2,543,891
Vydate				
phorate	36,967	31,492	2.7	$499,055
Thimet				
propargite	62,088	39,178	3.4	$1,204,500
Comite				
thiodicarb	40,528	52,973	4.6	$139,416
Larvin				

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the Central Valley is about $35.11.

Table 2. Insecticide and Miticide Use on Cotton in the Lower Desert Regions of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
acephate	19,950	33,202	115.3	$399,007
Orthene				
aldicarb	9,443	8,232	28.6	$259,961
Temik				
amitraz	133	558	1.9	$3,051
Ovasyn				
abermectin	-	58	0.2	$351
Zephyr				
bifenthrin	333	4,854	16.9	$69,890
Capture				
chlorpyrifos	1,408	2,944	10.2	$26,632
Lorsban				
cyfluthrin	21	599	2.1	$6,041
Baythroid				
cypermethrin	96	1,778	6.2	$11,095
Ammo				
dicofol	1,785	4,189	14.5	$50,206
Kelthane				
dimethoate	639	1,956	6.8	$6,297
Dimethoate				
fenpropathrin	4,984	23,207	80.1	$280,336
Danitol				
imidacloprid	16	529	1.8	$5,359
Provado				
lamba-cyhalothrin	17	777	2.7	$7,211
Warrior				
methamidophos	471	1,528	5.3	$11,140
Monitor				
oxamyl	1,384	2,693	9.4	$44,285
Vydate				
phorate	7,619	4,802	16.7	$102,859
Thimet				
propargite	123	75	0.3	$2,389
Comite				

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports).). Average insecticide (material) cost per acre treated for the lower deserts is about $44.65.

3. Insecticide and Miticide Use in an OP Free Pest Management System with Available Technology on Cotton in the Central Valley with High Insect Pressure

Material	**Rate Form/ac**	**# Appl./ Season**	**Pest**	**Notes**
aldicarb (Temik 15G)	3 lb	1/2	Spider mites	At-planting treatment
dicofol (Kelthane MF)	1 pt	1	Spider mites	Resistance Issues
Or				
propargite (Comite)	1 1/2 pt			
Or				
abamectin (Zephyr 0.15EC)	1/2 pt			
buprofezin (Applaud 70WP)	1/2 lb	1/4	Whiteflies	
Or				
Pyriproxyfen (Knack 0.86EC)	1/2 pt			
imidacloprid (Provado 1.6F)	1/8 pt	1	CA	Weak LB control, treated CA early before buildup
Or				
thiamethaoxam (Actara 25WDG)	1/4 lb			Treat CA early before buildup.
Or				
endosulfan (Thiodan 3EC)	2 pt			Treat CA early before buildup
aldicarb (Temik 15G)	14 lb	1	LB & CA	Potential for sustained migration to cause damage
cyfluthrin (Baythroid 2)	1/8 pt	1	LB	Potential CA outbreaks
Or				
lambda cyhalothrin (Warrior T)	1/4 pt			Potential CA outbreaks
Or				
bifenthrin (Capture 2EC)	1/4 pt			Potential CA outbreaks
methomyl (Lannate SP)	1/4 lb	1/2	Lep. Larvae	Potential leafminer outbreaks

Or		
indoxacarb (Steward)	2/3 lb	Selectively reduced risk
Or		
spinosad (Success 2SC)	1/4 pt	Selectively reduced risk
Or		
tebufenozide (Confirm 2F)	1 pt	Selectively reduced risk
Or		
Bacillus thuringiensis (Various Products)	1 lb	Selectively reduced risk

Table 4. Insecticide and Miticide Use in an OP Free Pest Management System with Available Technology on Cotton in the Central Valley with Low Insect Pressure

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
dicofol (Kelthane MF)	1 pt	1/4	Spider mites	Resistance Issues
Or				
propargite (Comite)	1 1/2 pt			
Or				
abamectin (Zephyr 0.15EC)	1/2 pt			
buprofezin (Applaud 70WP)	1/2 lb	1/10	Whiteflies	
Or				
Pyriproxyfen (Knack 0.86EC)	1/2 pt			
imidacloprid (Provado 1.6F)	1/8 pt	1/4	CA	Weak LB control, treat CA early before buildup
Or				
thiamethaoxam (Actara 25WDG)	1/4 lb			Treat CA early before buildup.
Or				
endosulfan (Thiodan 3EC)	2 pt			Treat CA early before buildup
aldicarb (Temik 15G)	14 lb	1/2	LB & CA	Potential for sustained migration to cause damage
Or				
cyfluthrin (Baythroid 2)	1/8 pt		LB	Potential CA outbreaks
Or				
lambda cyhalothrin (Warrior T)	1/4 pt			Potential CA outbreaks
Or				
bifenthrin (Capture 2EC)	1/4 pt			Potential CA outbreaks
methomyl (Lannate SP)	1/4 lb	1/8	Lep. Larvae	Potential leafminer outbreaks
Or				
indoxacarb (Steward)	2/3 lb			Selectively reduced risk

Or		
spinosad (Success 2SC)	1/8 pt	Selectively reduced risk
Or		
tebufenozide (Confirm 2F)	1 pt	Selectively reduced risk
Or		
Bacillus thuringiensis (Various Products)	1 lb	Selectively reduced risk

Table 5. Insecticide and Miticide Use in an OP Free Pest Management System with Available Technology on Cotton in the Lower Deserts with High Insect Pressure

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
dicofol (Kelthane MF)	1 pt	1	Spider mites	Resistance Issues
Or				
propargite (Comite)	1 1/2 pt			
aldicarb (Temik 15G)	14 lb	1	Spider Mite & LB	Potential for sustained migration to cause damage
buprofezin (Applaud 70WP)	1/2 lb	2	Whiteflies	
Or				
pyriproxyfen (Knack 0.86EC)	1/2 pt			
bifenthrin (Capture 2EC)	1/4 pt	1	LB	
Or				
fenpropathrin (Danitol 2.4EC	1 pt 1 pt			
indoxacarb (Steward)	2/3 lb	1/2	Lep. Larvae	Selectively reduced risk
Or				
spinosad (Success 2SC)	1/4 pt			Selectively reduced risk
Or				
tebufenozide (Confirm 2F)	1 pt			Selectively reduced risk
Or				
Bacillus thuringiensis (Various Products)	1 lb			Selectively reduced risk

Table 6. Insecticide and Miticide Use in an OP Free Pest Management System with Available Technology on Cotton in the Lower Deserts with Low Insect Pressure

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
aldicarb (Temik 15G)	14 lb	1/2	Spider Mite & LB	Potential for sustained migration to cause damage
buprofezin (Applaud 70WP)	1/2 lb	1	Whiteflies	
Or				
Pyriproxyfen (Knack 0.86EC)	1/2 pt			
bifenthrin (Capture 2EC)	1/4 pt	1/2	LB	
Or				
fenpropathrin (Danitol 2.4EC)	1 pt			
indoxacarb (Steward)	2/3 lb	1/4	Lep. Larvae	Selectively reduced risk
Or				
spinosad (Success 2SC)	1/4 pt			Selectively reduced risk
Or				
tebufenozide (Confirm 2F)	1 pt			Selectively reduced risk
Or				
Bacillus thuringiensis (Various Products)	1 lb			Selectively reduced risk

Table 7. Insecticide and Miticide Use in an OP Free Pest Management System with Emerging Technology on Cotton in the Central Valley

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
dicofol (Kelthane MF)	1 pt	1	Spider mites	Resistance Issues
Or				
propargite (Comite)	1 1/2 pt			
Or				
abamectin (Zephyr 0.15EC)	1/2 pt			
Or				
spirodicolfen (Envidor 2SC)	1 pt			Not registered
Or				
milbemectin (Mesa)	2pt			Not registered
triazamate (Aphidstar 50WP)	1/2 lb	1	CA	Not registered
Or				
pymetrozine (Fulfill 50 WDG)	1/8 lb			Not registered
Or				
imidacloprid (Provado 1.6F)	1/8 pt			Treat CA early before buildup
Or				
thiamethaoxam (Actara 25WDG)	1/4 lb			Treat CA early before buildup.
buprofezin (Applaud 70WP)	1/2 lb	1/10	Whiteflies	
Or				
pyriproxyfen (Knack 0.86EC)	1/2 pt			
aldicarb (Temik 15G)	14 lb	1	LB	Side-dress treatment
cyfluthrin (Baythroid 2)	1/8 pt	1/8	LB	Potential CA outbreaks
Or				
lambda cyhalothrin (Warrior T)	1/4 pt			Potential CA outbreaks

Or				
bifenthrin (Capture 2EC)	1/4 pt			Potential CA outbreaks
indoxacarb (Steward)	2/3 lb	1/2	Lep. larvae	Selectively reduced risk
Or				
emamectin benzoate (Demim 0.16EC**)**	1/2 pt			Selectively reduced risk Not registered
Or				
methozyfenoxide (Intrepid 2F)	1 pt			Selectively reduced risk Not registered
Or				
spinosad (Success 2SC)	1/4 pt			Selectively reduced risk
Or				
tebufenozide (Confirm 2F)	1 pt			Selectively reduced risk
Or				
Bacillus thuringiensis (Various Products)	1 lb			Selectively reduced risk

Table 8. Insecticide and Miticide Use in an OP Free Pest Management System with Emerging Technology on Cotton in the Lower Deserts

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
dicofol				
(Kelthane MF)	1 pt	1/4	Spider mites	Resistance Issues
Or				
propargite				
(Comite)	1 1/2 pt			
Or				
abamectin	1/2 pt			
(Zephyr 0.15EC)				
Or				
spirodicolfen	1 pt			Not registered
(Envidor 2SC)				
Or				
milbemectin	2pt			Not registered
(Mesa)				
buprofezin	1/2 lb	1	Whiteflies	
(Applaud 70WP)				
Or				
pyriproxyfen	1/2 pt			
(Knack 0.86EC)				
triazamate				
(Aphidstar 50WP)	1/2 lb	1/8	CA	Not registered
Or				
pymetrozine				
(Fulfill 50 WDG)	1/8 lb			Not registered
Or				
imidacloprid	1/8 pt			Treat CA early before
(Provado 1.6F)				buildup
Or				
thiamethaoxam	1/4 lb			Treat CA early before
(Actara 25WDG)				buildup.
aldicarb	14 lb	1	LB	Side-dress treatment
(Temik 15G)				
cyfluthrin	1/8 pt	1/8	LB	Potential CA outbreaks
(Baythroid 2)				
Or				
lambda cyhalothrin	1/4 pt			Potential CA outbreaks

(Warrior T)				
Or				
bifenthrin	1/4 pt			Potential CA outbreaks
(Capture 2EC)				
indoxacarb	2/3 lb	1/4	Lep. Larvae	Selectively reduced risk
(Steward)				
Or				
spinosad	1/4 pt			Selectively reduced risk
(Success 2SC)				
Or				
tebufenozide	1 pt			Selectively reduced risk
(Confirm 2F)				
Or				
emamectin benzoate	1/2 pt			Selectively reduced risk
(Demim 0.16EC)				Not registered
Or				
methozyfenoxide	1 pt			Selectively reduced risk
(Intrepid 2F)				Not registered
Or				
Bacillus thuringiensis	1 lb			Selectively reduced risk
(Various Products)				

GRAPES

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California ranks first in grape production in the United States and grapes are ranked second in value of all California agricultural commodities. Production is divided into fresh market/table, raisin and wine grapes. A total of 775,901 acres of grapes were harvested in 1998, of which 269,843 acres (39%) were planted with raisin grape varieties, 342,547 acres (49.5 %) were wine grapes and about 115,000 acres (16%) were table grapes. The leading production counties include Fresno, Tulare, Kern, San Joaquin and Madera.

There are four major areas of production in the state. These include the southern San Joaquin Valley (470,289 acres), northern San Joaquin Valley and Sacramento Valley (131,632 acres), coastal (152,734 acres) and desert (16,771 acres). The southern San Joaquin Valley region produces 99% of California's raisin crop, 85% 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 Valley and Sacramento Valley focuses almost exclusively on wine grapes. Northern San Joaquin Valley and Sacramento Valley produces about 20% of the state's wine grapes. The desert (Coachella Valley) produces primarily table grapes.

Arthropod pests are similar throughout the state for raisin, table and wine grapes. However, the relative severity rating of these pests differs from area to area. The methods of control are similar, but the need and frequency of control differs greatly. There are some minor differences in susceptibility to pests based on grape cultivar. However, there are greater differences in pest susceptibility based on the cultural manipulation for markets than that based on grape cultivar. For instance, pest severity differs on Thompson seedless cultivar based on whether it is grown for wine, raisin or table grape markets. Due to cosmetic appearance, table grape has a lower threshold level for many pests. Based on the 1999 California Department of Pesticide Use Report for Grapes, only 5.5 % of the acreage was treated with an organophosphate (OP) insecticide and only 3.5 % of the total lbs AI (active ingredient) of insecticides were OP insecticides.

The key insect pest of grapes throughout the state is leafhoppers. The relative importance of other pests depends on the type of grape crop being produced and the region. Some of the more common pests include spider mites, mealybugs, leafrollers, western grape sceletonizer, thrips, sharpshooters and phylloxera.

Grape and Variegated Leafhoppers

Grape Leafhopper (GLH), *Erythroneura elegantula*
Variegated Leafhopper (VLH), *Erythroneura variabilis*

Leafhoppers are major pests of all grape crops in the state of California. The GLH is a major pest of grapes north of the Tehachapi Mountains, primarily in the northern San Joaquin Valley region and the north coast region. It has occasionally been a problem in the coastal valleys (central and south coast regions). The VLH is a major pest of grapes in southern California (Coachella Valley regions) and as far north as the northern San Joaquin Valley region.

Adults and nymphs feed on leaves by puncturing leaf cells and sucking out the contents, ultimately leaving white spots at feeding sites. As the amount of damage increases leaves may lose photosynthetic activity, turn brown and fall off the vine. While studies suggest that grapevines can tolerate fairly high leafhopper populations, heavy spotting on table grapes can contribute to economic losses before effects on yield loss or soluble solids is noticed. Actual leafhopper damage varies according to location of the vineyard, variety, plant vigor, market use of the variety and season. However, studies have shown that VLH causes some 60% more damage, over a given leaf area, than the GLH. Large adult leafhopper populations at harvest can annoy pickers by flying into their faces and nymphs may attempt to pierce exposed skin, both leading to reduced productivity of fieldworkers.

The most important natural enemy of the GLH and VLH is the egg parasitic wasp *Anagrus erythroneurae*. Since GLH and VLH overwinter as adults, survival of this parasite depends upon the ready availability of other leafhopper eggs to overwinter. Some overwintering hosts for *Anagrus* are blackberry leafhopper eggs on blackberries near streams and prune or apple leafhopper eggs. *Anagrus* is not as effective on VLH as it is on GLH, and economic control of VLH is usually not achieved by parasitism alone. Spiders are the dominant predators on grapes in the San Joaquin Valley. Other predators of leafhoppers include green lacewings, minute pirate bugs, nabid bugs, big-eyed bugs, lady beetles and the predatory mite *Anystis agilis*.

Although leafhoppers infest most vineyards in California, they may not require chemical treatment since most vineyards can tolerate fairly high populations without harm, with GLH populations being easier to tolerate than VLH. Between 20% to 40% of wine and raisin grape vineyards require treatment, while most table grape vineyards require at least one treatment a year. Within the last five years the insecticide imidacloprid (Provado/Admire) has been registered for leafhopper control and it is extremely effective and relatively non-disruptive to beneficial arthropods in the vineyard. Single applications, often at lower than labeled rates of Provado/Admire, have provided season long control. Prior to registration of Provado, materials such as dimethoate (Dimethoate), naled (Dibrom), carbaryl (Sevin) or methomyl (Lannate) were used. The use of these insecticides has been significantly reduced or eliminated because of worker reentry concerns and secondary effects on beneficial arthropods.

Spider Mites

Willamette Mite (WM), *Eotetranychus willamette*
Pacific Spider Mite (PSM), *Tetranychus pacificus*

Webspinning spider mites are a major pest of raisin and wine grapes and can be a major pest of table grapes, depending largely on the environmental conditions and the soil type in which they are grown. The PSM is the most important mite species with the WM being less common and generally less damaging.

Feeding damage by PSM and WM begins as small, yellow spots. As damage progresses, these spots may turn brown (necrotic). WM feeding causes foliage to turn yellowish bronze or red (depending upon the variety), but usually no burn occurs unless vines are weak. High populations may cause leaf burning, which can decrease photosynthesis. WM are primarily a problem in foothill, coastal region, northern San Joaquin Valley and Sacramento Valley. PSM are primarily a problem in the southern San Joaquin Valley.

The western predatory mite *Galendromus occidentalis* is commonly present in vineyards and can be effective in reducing all stages of spider mite populations. However, insecticides and sulfur applications may reduce the numbers of this beneficial mite. Predatory mites are available commercially to augment field populations. General predators including sixspotted thrips, minute pirate bugs and the spider mite destroyer. To preserve these natural enemies, growers should avoid using disruptive insecticides, especially Sevin, Dimethoate, dicofol (Kelthane) and Lannate.

Propargite (Omite) is an organosulfur and has typically been applied to approximately 38% of the table and raisin grape acreage and about 10% of wine grape acreage. Fenbutatin-oxide (Vendex) is another common treatment used for mite control that was applied to approximately 6.5% of table and raisin grape acreage and to about 3% of the wine grape crop. Narrow range oils, cinnemaldehyde (Valero) and insecticidal soaps have also been used at varying degrees. These products are contact materials requiring low populations and good coverage for effective control. In the past two years the following reduced-risk materials have been registered for grapes: avermectin (Agri-mek) and pyridaben (Pyramite/Nexter).

Mealybugs

Grape Mealybug (GM), *Pseudococcus maritimus*
Vine Mealybug (VM), *Planococcus ficus*
Obscure Mealybug (OM), *Pseudococcus viburni*
Longtailed Mealybug (LM), *Pseudococcus longispinus*

There are four species of mealybugs found in California grapes. Only the GM is native to the United States. The GM was first identified in California and it is found in all major grape growing areas with the exception of southern California. In the Coachella Valley the VM predominates and infests virtually 100% of the grapes grown. VM has recently been found in Kern and Fresno counties where severe quality reduction has occurred in both table and raisin grapes. The obscure and longtailed mealybugs are found only in the coastal growing areas.

In the San Joaquin Valley, GM does little or no harm to vines, but contaminates fruit with cottony egg masses, immature larvae, adults and honeydew or black sooty mold growing on honeydew. The damage is related to the level of contamination and the eventual use of the grapes. Table grapes may become unsightly while raisin or wine grapes may be difficult to process. High levels of infestation may lead to crop rejection and heavy economic losses. Raisin and wine grapes can tolerate much greater populations than table grapes. Raisin and wine grapes may be heavily infested at times without economic loss. Insecticide treatments used to control leafhopper usually disrupt natural predators that suppress mealybug populations and damaging populations of mealybug can follow an insecticide application for leafhoppers. In the central coast, obscure mealybugs have caused severely stunted wine grapevines and led to crop losses. The VM can potentially cause far greater damage than the other mealybugs, as it feeds on leaves, shoots and roots which can severely stunt vine growth. VM can also contaminate grape bunches with honeydew, producing far greater amounts of honeydew than the GM. The VM may have up to eight generations per year in the San Joaquin Valley compared with two to four for the GM.

While many species of parasitic wasps are known to attack grape and longtailed mealybugs (e.g. *Acerophagus notativentris, Pseudophycus angelicus, Zarhopalus corvinus,* etc.) their impact differs between regions and time. The predator mealybug destroyer *Cryptolaemus montrouzieri* also plays a varying role in control.

The optimum chemical control for all these species has been chlorpyrifos (Lorsban) applied in March prior to bud break. This single application has given adequate season long control in most situations. However, recently, the application of Admire to the soil has shown equal efficacy but this application is only effective where drip irrigation is used. Under flood irrigated conditions Admire is not effective. The cost of 16 ounces of Admire is considerably more expensive than the Lorsban. Lorsban is also sprayed onto the soil surface during spring to kill ants, which are known to ward off natural enemies. Thus the use of Lorsban for ant control allows for an IPM program.

Leafrollers and Western Grapeleaf Skeletonizer

Omnivorous Leafroller (OLR)*, Platynota stultana*
Orange Tortrix (OT)*, Argyrotaenia citrana*
Grape Leaffolder (GL), *Desmia funeralis*
Western Grapeleaf Skeletonizer (WGS), *Harrisina brillians*

The OLR (San Joaquin and Sacramento valleys), the OT (coastal growing areas), the GL and WGS have historically been chemically controlled with the pesticide cryolite (Prokil or Kryocide). Each of these pests can also be managed with two to three applications of *Bacillus thuringiensis* (Bt). Carbamate and OP insecticides are sometimes used. The most commonly used products include phosmet (Imidan), carbaryl or Lannate. The use of these products often results in spider mite outbreaks in the vineyard. Loss of OP insecticides for these pests would not result in a production problem.
More recently, OLR has been controlled with mating disruption. This has not been attempted for OT or GL. Tebufenozide (Confirm) has been registered for OLR control. GL is a much more sporadic pest and quite often controlled biologically with the parasitoid *Bracon cushmani*. Also, viral pathogens and parasitoids have been associated with a major decline in the pest status of WGS.

Thrips

Western Flower Thrips, *Frankliniella occidentalis*
Grape Thrips, *Drepanothrips reuteri*

There are two common pest thrips found in grapes, the western flower thrips and the grape thrips. Both species are considered a minor problem in wine and raisin grapes. Feeding in actively growing shoot tips during cold spring weather causes stunted shoot growth. In table grape varieties such as Thompson seedless, red globe and white Malaga thrips can be a serious problem. Grape thrips is the least damaging and primarily affects vine growth although white Malaga are subject to fruit scarring caused by feeding. Italia, Calmeria and Thompson seedless cultivars are susceptible to western flower thrips feeding and oviposition. Thrips feeding result in halo and star burst scarring. This damage is much more severe where migration of thrips occurs from native vegetation in April and May. The severity of this damage is related to the length of time that flower caps remain attached to the individual berry. Currently the only effective material for flower thrips control is Lannate.

Sharpshooters

Glassy-winged Sharpshooter (GWSS), *Homalodisca coagulata*
Blue-green Sharpshooter (BGSS), *Graphocephala atropunctata*
Green Sharpshooter (GSS), *Draeculacephala minerva*
Red-headed Sharpshooter (RHSS), *Carneocephala fulgida*

Sharpshooters vector the bacterium *Xylella fastidiosa*, which causes Pierce's disease in grapevines. Recently the establishment of the GWSS in the Temecula wine region of southern California and the southern part of Kern County, has led to an increase in insecticide use. The BGSS is the most important vector of the bacteria in coastal grape-growing regions. The GSS and RHSS are the most important vectors in the San Joaquin Valley.

Areawide pest management strategies have been implemented in both Riverside and Kern counties to combat GWSS. Initially, in southern California, OP insecticides were used to combat this pest. Presently areawide pest management strategies rely on several applications of Provado, Admire, Lannate, Sevin and kaolin clay (Surround).

Riparian areas bordering vineyards are an important source of BGSS in coastal vineyards. Vegetation management is used to remove plant species that are systemic hosts of the bacteria and breeding hosts of BGSS. In the vineyard, BGSS are controlled with Provado/Admire. Dimethoate is the only product currently available that can be applied to riparian vegetation under a Special Local Need (SLN) permit. Control of green and RHSS is best achieved by weed removal where these sharpshooters breed.

Grape Phylloxera (GP), *Daktuloshphaira vitifoliae*

A native of North America, GP can be a significant pest of grapes attacking vinifera grape roots, and may lead to stunted growth and vine death. GP have been found through all of California's grape-growing areas except for southern California. GP prefers heavy, clay soils that are found in the cooler grape-growing regions of the state such as Napa, Sonoma, Lake, Mendocino and Monterey counties, as well as the Sacramento Delta and the foothills. It will also take advantage of vines that are stressed or have a limited root area. Although GP is present in the heavier soils of the San Joaquin Valley (mostly the foothill areas), damage is not as severe, possibly because soils are deeper and water more plentiful, or because GP does not do well in the warm summer temperatures of the valley. GP is not a pest on deep, easily drained or sandy soils.

Once established on a root, GP feeding causes swelling which can impair uptake of water and nutrients and eventually lead to root decay. Infested vineyard areas often rapidly expand concentrically. Damage in a vineyard initially appears as a few stunted or dead vines. The severity of infestation differs depending on rootstock variety, vine age, plant vigor, soil type/drainage and temperature.

Choosing the proper rootstock, sanitary practice, and water and fertility management are of key importance in controlling GP. A pesticide treatment will not eradicate GP populations because of the difficulties in penetrating the heavy soils that this pest prefers. The OP insecticide fenamiphos (Nemacur) is applied to limited acreage for phylloxera control as well as carbofuran (Furadan) and sodium tetrathiocarbonate (Enzone).

Nematodes

Endoparasitic Nematodes:
- Root Knot Nematodes:
  - *Meloidogyne incognita*
  - *M. javanica*
  - *M. arrenaria*
  - *M. hapla*
- Root Lesion Nematode, *Pratylenchus vulnus*
- Citrus Nematode, *Tylenchulus semipenetrans*

Ectoparasitic Nematodes:
- Ring Nematode, *Criconemella xenoplax*
- Dagger Nematode, *Xiphinema americanum* & *X. index*

Dagger, ring and lesion nematodes are most prevalent in north and central coast vineyards and in the San Joaquin Valley. Root knot and citrus nematodes occur most commonly in the San Joaquin Valley and southern California.

Plant parasitic nematodes feed on roots, reducing vigor and yield of the vine usually in irregular patterns across the vineyard. Nematodes fall into two categories with respect to feeding: some penetrate into roots and feed internally (endoparasitic) and some feed externally on roots (ectoparasitic). Damage is often associated with soil texture. Root knot nematode is most damaging on coarse-textured soils (sands, loamy sands and sandy loams). Ring nematode can cause damage on coarse or fine-textured soils, but does not do well on fine sandy loam soils. The dagger nematode *X. americanum* vectors a yellow vein virus (also known as tomato ringspot virus). *X. index* vectors the grapevine fanleaf virus.

To naturally rid an old vineyard site of the effects of *X. index* and grapevine fanleaf virus, it is necessary to forgo planting grapes for more than 10 years. No single rootstock is resistant to all root knot nematodes. Selection of a rootstock is a risky endeavor because of their excessive or inadequate growth in certain situations and their limited breadth of resistance. Manure and other soil amendments can improve vine vigor and frequently reduce the effect of nematode infestation. Preventive measures include avoiding soil compaction and stratification, improving soil tilth and drainage and proper irrigation and fertilization.

Vineyards planted in fumigated ground are known to have improved growth and yields compared to those planted on non-fumigated ground. Methyl bromide is estimated to be applied to approximately 45% of new vineyard land and 90 % of replanted vineyards. However, in any one year, only a small percent of vineyard land is fumigated. Other pre-plant materials are metam sodium (Vapam) and the organochlorine 1,3 – Dichloropropene (Telone).

Post-plant registered chemicals are Nemacur, Furadan and Enzone. Enzone and Furdan are most effective against ectoparasitic nematodes and Nemacur is most effective against endoparasitic nematodes.

Current - Pest Management Program

Coastal Regions

The coastal regions include all coastal counties from San Diego to Humbolt County and contain approximately 153,000 acres of wine grapevines. Insects and mites are not a significant problem in grapes in the coastal region with about half of the acreage receiving a miticide or insecticide (Table 1). OP insecticide used on less than 6% of the acreage. Control of GLH relies on the egg parasitic wasp *Anagrus* and most vineyards can tolerate fairly high GLH populations. Thus, chemical control is not always needed. In 1999, Provado/Admire was applied to about 18% of the coast region acreage mainly for leafhopper control. Spider mites are also under good biological control and only infrequently require chemical control. Approximately 13% of the acreage received a miticide (Omite, Kelthane or fenbutatin-oxide (Vendex)) in 1999. The obscure and longtailed mealybugs are restricted to relatively few areas in coastal regions, 1.4% of the acreage was treated with Lorsban in 1999. Recently, the soil application of Admire has shown to be as efficacious as Lorsban. But, Lorsban is the most effective chemical for ant control. Controlling ants in mealybug infected vineyard is important to allow the natural enemies to control the mealybugs. BGSS is the major vector of the bacteria that causes Pierce's disease in coastal vineyards. Riparian vegetation management is one strategy being used when appropriate to reduce the number of BGSS entering the vineyard. Provado is used in the vineyard for control of BGSS. However, Dimethoate is the only chemical that can be applied to the riparian vegetation under a SLN permit. In 1999 2.1% of the acreage was sprayed with Dimethoate. In coastal regions the most prevalent nematodes are dagger, ring and lesion nematodes. In 1999 Nemacur was applied to 2% of the acreage. The average insecticide (material) cost per acre treated for the coastal region is approximately $15.

Southern San Joaquin Valley Region

The southern San Joaquin Valley region includes Fresno, Kern, King, Madera and Tulare counties and contains approximately 470,000 acres of raisin, table and wine grapevines. On wine and raisin grapes, PSM are the major pest, followed by VLH, OLR and VM. On table grapes, GM and VM are the major pests with the exception of 10,000 acres in southern Kern County where GWSS is the major pest. Followed in importance to these are OLR, VLH, PSM, thrips and WGS.

Due to the warmer climate, insects and mites can be a significant problem in grapes in the southern San Joaquin Valley region. Vineyards received about two and quarter applications of a miticide or insecticide but less than a quarter of the acreage was treated with an OP insecticide in 1999 (Table 2). Approximately half of the acreage received an application of a miticide for spider mite control. Omite was the primary miticide used in 37.6% of the acreage. Other miticides used were Vendex and Kelthane. VLH, GM and VM were controlled with Provado/Admire, applied to approximately 43% of the acreage in 1999. Approximately 7% of the acreage received the OP insecticide Lorsban for mealybug and ant control. There are a number of lepidopteran pests of which OLR is the most important. Control of OLR relies primarily on Kryocide (68% of the acreage) or repeated applications of Bt. Other products used are Lannate, Imidan and Sevin used for late-season control. GWSS is being controlled with Provado/Admire, carbaryl, Lannate and kaolin clay. In table grapes thrips are controlled with Lannate. Root knot nematode is the most prevalent nematode in the San Joaquin Valley. In 1999, Nemacur was applied to 9% of the acreage. The average insecticide (material) cost per acre treated for the southern San Joaquin region is approximately $42.

Northern San Joaquin and Sacramento Valleys Region

The northern San Joaquin and Sacramento Valley regions includes the Central Valley counties from Merced to Tehama and contains approximately 132,000 acres of wine grapevines. Insects and mites are not a significant problem in grapes in the northern San Joaquin and Sacramento valleys region with about one and a half applications of a miticide or insecticide but less than 4% of the acreage treated with an OP insecticide in 1999 (Table 3). VLH and SM are the primary pests in this region, followed by OLR. Provado/Admire applied primarily for VLH control was applied to approximately 39% of the acreage (Table 3). In 1999, 50% of the acreage was treated with a miticide. The primary miticide used was Omite on 35% of the acreage followed by Kelthane (8%) and Vendex (6 %). Control of OLR relies on repeated applications of Bt or Kryocide (12% of the acreage). Approximately 3% of the acreage was treated with Nemacur. The average insecticide (material) cost per acre treated for the northern San Joaquin region is approximately $27 per acre.

Lower Desert Region

The desert region includes Riverside, San Bernardino and Imperial counties and contains 16,770 acres of primarily table grapes in the Coachella Valley and approximately 2,000 acres of wine grapes in Temecula. VM is the key pest in the Coachella Valley affecting all 17,000 acres and GWSS is the key pest in the wine grape region of Temecula. With the exception of vine mealybug, a newly introduced invasive species, insects and mites are not a significant problem in the desert region. Desert acreage received approximately half an application of an insecticide but a quarter of the acreage was treated with an OP insecticide in 1999 (Table 4). Miticides are not used in the lower desert region. VM, VLH and GWSS are controlled with Provado/Admire. Provado/Admire was the most widely used insecticide with about a quarter of the acreage treated. Only three OP insecticides (Lorsban, Dimethoate and Nemacur) were used to any extent in the lower desert region. Lorsban and Dimethoate was used for VM and ant control and was applied to 5.7 and 8.2% of the acreage, respectively while Nemacur was applied to 9% of the acreage. The average insecticide (material) cost per acre treated for the lower desert region is approximately $27 per acre.

OP Free – Pest Management Program with Available Technology

The OP free programs below were constructed with currently registered insecticides for immediate implementation and without regard to resistance management consequences. Eliminating OP insecticides from grape production would have minor impact with the exception of blue-green sharpshooter control on riparian vegetation in the north coast, mealybug control in vineyards under flood irrigated conditions, ant control in vineyards with high populations of mealybugs, and root knot nematode in the southern San Joaquin Valley and Coachella Valley.

Coastal Region

An OP insecticide free pest management program with available technology in the coastal region would be very similar to the current pest management program since the use of OP insecticides is very low. Only about 5% of the acreage is treated with an OP insecticide. Control of GLH and BGSS would rely on Provado/Admire on about 25% of the acreage while spider mites that are usually under good biological control would require a miticide on about 10% of the acreage (Table 5). Bt or Kryocide would be used on about 10% of the acreage for OT, WGS and GL control. Lannate will be used for thrips control and Enzone will be used for nematode control on about 10% of the acreage.
The most significant impact in the loss of OP would be the elimination of Dimethoate. Dimethoate is the only product allowed in the riparian corridor for control of BGSS. BGSS vectors the bacterium that causes Pierce's disease, one of the few grapevine diseases that kills vines. The area most affected by the elimination of Dimethoate would be the north coast that accounts for about 2/3 of coastal acreage. Yield loss (vine death) would be expected to occur in vineyards adjacent to the riparian corridor. Approximately 5% of the north coast acreage would be at risk for vine death. It is estimated that 5% of the north coast acreage corresponds to about the first 200 to 300 ft adjacent to the riparian corridor. Where the riparian corridor is wide, vegetation management can reduce the number of BGSS. Also, disease infections that occur late in the growing season can be pruned out during the fall and winter. However, the vine loss is expected to be substantial.

Loss of Lorsban would impact sugar-feeding ant control in vineyards. The sugar-feeding ants protect mealybugs from beneficial insects. The mealybugs produce honeydew that is fed upon by the sugar-feeding ants. Without Lorsban, higher mealybug infestations would be expected and mealybug control would rely on Admire. Admire would be applied through the drip system. This would impose a significant financial hardship for those growers that are not drip irrigating and would require the installation of drip irrigation system. However, most growers in the coastal region are on drip irrigation. Applications of Provado would not be effective for mealybug control because of the short residual activity of Provado.

The ectoparasites, dagger and ring nematodes, along with the endoparasite, root lesion nematode, are the most prevalent nematodes in coastal vineyards. Ectoparasites are well controlled with two applications of Enzone. Presently there are no effective alternatives to Nemacur for the control of endoparasitic nematodes. If endoparasitic nematodes become a problem the only long-term solution is to remove the orchard and fumigate with methyl bromide, Vapam or Telone II.

Southern San Joaquin Valley Region

The major pests of wine and raisin grapes are spider mites, followed by VLH, OLR and VM. On table grapes, GM and VM are the major pests with the exception of 10,000 acres in southern Kern County where GWSS is the major pest. Control of spider mites would rely on one of a number of miticides applied to about 50% of the acreage (Table 6). Control of GLH would rely on Provado that would be applied to about 50% of the acreage while VM and GM would rely on Admire applied through the drip irrigation system to about 10% of the acreage. The application of Admire would also control GLH populations. Control of WGS, OLR, GL or other lepidopterous larval pests would rely on one application of Bt or Kryocide.

Loss of OP insecticides particularly Lorsban in the southern San Joaquin Valley would greatly affect ant control and corresponding mealybug control on flood irrigated vineyards as discussed above. Also, nectar producing cover crops of 80% common vetch and 20% merced rye are being planted in VM affected areas of the southern San Joaquin Valley. The ants are attracted to the cover crop and do not tend the mealybugs. This has worked for some species of ants, allowing parasites to control the mealybugs. VM was introduced into Fresno County in 2000 and has spread to 2,000 acres in the last two years. Without mealybug control yield losses could be as high as 40%. Between VM and GM about 10,000 acres are at risk.

Less than 5% of the acreage was treated with Imidan for leafroller control in 1999. The use of Imidan is applied for late-season control of OLR and GL since wineries restrict the use of Kryocide after bloom. However, the loss of Imidan should not pose a significant problem for grape growers. There are several insecticides registered for leafroller control and recently tebufenozide (Confirm) has been registered for OLR and GL control.

In the southern San Joaquin Valley the endoparasitic root knot nematode is the most common nematode found. Loss of Nemacur would affect approximately 40,000 acres. Presently there are no effective alternatives to Nemacur for the control of endoparasitic nematodes. If endoparasitic nematodes become a problem the only long-term solution is to remove the orchard and fumigate with methyl bromide, Vapam or Telone II.

Northern San Joaquin and Sacramento Valleys Region

An OP insecticide free pest management program with available technology in northern San Joaquin and Sacramento valleys region would be very similar to the current pest management program since the use of OP insecticides is very low. Only about 3.7% of the acreage is treated with an OP insecticide and 2.7% of the OP insecticide use is Nemacur. Thus the loss of OP insecticides would be negligible. VLH and PSM/WM are the primary pests in this region, followed by OLR. Provado would be applied primarily for VLH control to about 20% of the acreage, while a miticide would be applied to about 20% of the acreage for PSM/WM (Table 7). Control of OLR, WGS, GL or other lepidopterous pests would rely on an application of Bt, MVP II or Kryocide. The loss of Nemacur would only impact vineyards with endoparasitic nematodes. Ectoparasitic nematodes would be controlled with two applications of Enzone.

Lower Desert Region

The key insect pest in fresh market grapes in the Coachella Valley is VM while GWSS is the key pest in the wine grape region of Temecula area. With the exception of VM and GWSS, newly introduced invasive species, insects and mites are not a significant problem in the desert region. Desert acreage received about one application of an insecticide but only a quarter of the acreage was treated with an OP insecticide in 1999. However, the loss of the OP insecticides would require the growers to shift to one application of Admire that would be applied through the drip irrigation for control of VM, VLH and GWSS (Table 8). This would impose a significant financial hardship for those growers that are not drip irrigating and would require the installation of drip irrigation system. Those growers that do not install a drip irrigation system would suffer about 40% yield loss. A large amount of acreage in the desert region is not on drip irrigation. In the desert region the endoparasitic root knot nematode is the most common nematode found. Loss of Nemacur would affect approximately 2,000 acres and would over time require the orchards to be removed and fumigated with methyl bromide, Vapam or Telone II when infested to a high degree. Ectoparasites are well controlled with two applications of Enzone.

OP Free – Pest Management Program with Emerging Technology

The IPM program below was constructed with currently registered insecticides and/or insecticides that are anticipated to be registered within four to five years and technologies that would require a greater reliance on cultural and biological alternatives (Table 9). The IPM program with emerging technology would produce a stable long-term program that would allow for much greater impact of beneficial insects and mites on the pest populations. The number of applications as well as the selection of material will depend on the growing area and pest pressure.

Leafhopper populations can be reduced through irrigation practices. Because leafhoppers prefer vigorous growing and lush vegetation, preventing overly vigorous vine growth may help manage leafhoppers. In grapes grown for wine, water deficiency between petal fall and veraison improves wine quality and can decrease leafhopper populations. It is also important to manage nitrogen fertilization to avoid excessive growth. Grape leafhoppers are controlled by the egg parasitoid *Anagrus* in coastal regions. Provado/Admire (Provado) is an effective insecticide that can be used at low rates and has low impact on natural enemies. It is toxic to aquatic organisms, thus drift into waterways should be avoided. Increased reliance on Provado may cause leafhoppers to develop resistance to this material. If used early in the season before populations are high narrow range oil is effective at diminishing leafhopper populations. The particle film kaolin (Surround) is a leafhopper feeding deterrent and must be used before veraison to avoid white clay residue on the fruit at harvest. Pyridaben (Pyramite) has recently been registered though it is harder on natural enemies and considerably more expensive. Other insecticides need to be registered to use in rotation with Provado. Possible candidates may be the insect growth regulator buprofezin (Applaud).

Spider mites, in particular PSM, are favored when the vines are stressed. Maintaining adequate vine water status decreases the risk of spider mite outbreaks. Cover crops can increase water penetration and reduce dust. Propargite (Omite) is the miticide most widely used, and even though it is not an OP its use may be lost or restricted due to the implementation of the FQPA. Pyridaben (Nexter or Pyramite) and Agri-Mek have recently been registered on grapes. Contact materials such as narrow range oil can be used at low population levels early in the season to delay the development of the population by three to four weeks. Clofentezine (Apollo) is an effective, though expensive, possible candidate for registration on grapes.

OLR is a pest primarily in the San Joaquin Valley. Habitat for OLR can be reduced through intensive weed management and removing and burying unharvested grape clusters. The vast majority of the acreage is treated with the mineral Kryocide and to a lesser degree with Bt. Wineries restrict the use Kryocide after bloom for fears of sulfite residue in the wine. The recently registered insect growth regulator tebufenozide (Confirm) can be used for late season infestations. Spinosad (Success) is very effective against leafrollers and is a possible candidate for registration on grapes.

Obscure mealybugs can cause severe damage in the central coast and the newly introduced vine mealybug has affected the entire Coachella Valley and spread to the San Joaquin Valley. The only effective mealybug material is Admire applied through the drip. To avoid the development of resistance to this material other chemicals need to be registered. A possible candidate is the insect growth regulator (Applaud). Because ants interfere with biological control, ant baits containing boric acid, or spinosad, are possible candidates for registration.

In the north coast control of BGSS in the riparian corridor can be achieved in some locations by vegetation management. Few insecticides have the possibility to be registered for application on riparian vegetation because of concerns of toxicity to aquatic organisms. Surround can be applied as a buffer strip next to the riparian corridor. However, more research is needed to evaluate if Surround would prevent the transmission of Pierce’s disease. In the Temecula wine growing area and in Kern County GWSS is a very real threat to the grape production of those areas. GWSS has also spread to several cities in the Central Valley and Santa Clara County where they are being contained. GWSS can be controlled with several pyrethroids and neonicotinoid insecticides such as Admire. Admire and Danitol (fenpropathrin) are presently registered. Surround is used in a buffer strip next to citrus to deter feeding and the movement into grapes.

Ectoparasitic nematodes can be controlled with two applications of Enzone. Presently there are no substitutes to control endoparasitic nematodes such as root-knot nematode that affect primarily the southern San Joaquin Valley and the Coachella Valley. Admire appears to have some effect on root-knot nematode but further studies are needed.

Addendum

One new insecticide, buprofezin (Applaud), and one new miticide, bifenazate (Acramite), have been registered in grapes since the economic analysis. Applaud will be used for leafhopper and mealybug control and will complement the use of Provado/Admire. The complementary use of Applaud may slow the development of mealybug resistance to Provado/Admire. However, Applaud will adversely effect the mealybug destroyer, which is a major predator of both the grape and longtailed mealybugs in the northern part of the state. The mealybug destroyer is not an important predator of the vine mealybug and the vine mealybug is becoming an increasing important pest of grapes. Thus Applaud along with Provado/Admire will increase in use as the vine mealybug spreads. Acramite will be added to the existing arsenal of miticides, e.g., propargite (Omite), abermectin (Agri-Mek) and fenbutatin-oxide (Vendex). Acramite will increase the number of available miticides and hopefully reduce or contain miticide costs.

Table 1. Insecticide and Miticide Use on Grapes in the Coastal Regions of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
Bacillus thuringiensis (Various Products)	787	9,057	4.3	$24,315
carbaryl (Sevin)	3,524	2,292	1.1	$24,526
chlorpyrifos (Lorsban)	5,176	3,017	1.4	$97,928
cryolite (Kryocide, Prokil)	66,168	11,212	5.3	$166,082
dicofol (Kelthane)	10,589	9,506	4.5	$297,754
dimethoate (Dimethoate)	1,626	4,431	2.1	$16,012
encap.-delta-endotoxin (MVP, MVP II)	75	170	<0.1	$1,336
fenamiphos (Nemacur)	9,142	4,244	2	$106,776
fenbutatin-oxide (Vendex)	5,988	6,410	3.1	$331,404
horticultural oil (Various Products)	48,011	67,920	32.4	$26,406
imidacloprid (Admire, Provado)	2,136	38,393	18.3	$727,142
methomyl (Lannate)	8,037	16,805	8	$178,580
phosmet (Imidan)	54	27	<0.1	$560
propargite (Omite)	19,188	11,611	5.5	$372,247
sodium-tetrathiocarbonate (Enzone)	213,652	8,255	3.9	$655,911

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the coastal region is about $14.43

Table 2. Insecticide and Miticide Use on Grapes in southern San Joaquin Valley of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
Bacillus thuringiensis (Various Products)	14,430	171,347	35	$445,592
carbaryl (Sevin)	10,364	5,755	1.2	$72,134
chlorpyrifos (Lorsban)	60,512	33,557	6.9	$1,144,881
cryolite (Kryocide, Prokil)	1,846,174	334,684	68.4	$4,633,896
dicofol (Cyfluthrin)	16,936	15,684	3.2	$476,252
dimethoate (Dimethoate)	13,481	8,302	1.7	$132,788
encap.-delta-endotoxin (MVP, MVP II)	14,305	29,443	6	$254,209
fenamiphos (Nemacur)	58,578	44,220	9	$684,196
fenbutatin-oxide (Vendex)	27,743	31,742	6.5	$1,535,298
horticultural oil (Various Products)	134,996	48,225	9.9	$74,248
imidacloprid (Admire, Provado)	7,222	208,755	42.6	$2,458,772
methomyl (Lannate)	28,553	40,781	8.3	$634,445
phosmet (Imidan)	26,858	20,842	4.3	$278,252
propargite (Omite)	335,177	183,963	37.6	$6,502,428
sodium-tetrathiocarbonate (Enzone)	318,250	11,974	2.5	$977,026

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the southern San Joaquin Valley is about $41.48

Table 3. Insecticide and Miticide Use on Grapes in northern San Joaquin and Sacramento Valleys of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
Bacillus thuringiensis (Various Products)	2,017	37,573	26.9	$62,282
carbaryl (Sevin)	8,993	5,468	3.9	$62,588
chlorpyrifos (Lorsban)	444	228	0.2	$8,404
cryolite (Kryocide, Prokil)	90,553	16,166	11.6	$227,288
dicofol (Cyfluthrin)	12,108	11,260	8.1	$340,480
dimethoate (Dimethoate)	439	500	0.4	$4,323
encap.-delta-endotoxin (MVP, MVP II)	3,049	8,427	6	$54,179
fenamiphos (Nemacur)	7,683	3,798	2.7	$89,733
fenbutatin-oxide (Vendex)	6,454	8,875	6.3	$357,153
horticultural oil (Various Products)	54,189	32,556	23.3	$29,804
imidacloprid (Admire, Provado)	1,997	54,604	39	$679,782
methomyl (Lannate)	440	614	0.4	$9,772
phosmet (Imidan)	655	552	0.4	$6,790
propargite (Omite)	79,677	48,871	34.9	$1,545,728
sodium-tetrathiocarbonate (Enzone)	89,854	2,810	2	$275,851

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the northern San Joaquin and Sacramento Valleys about $26.83

Table 4. Insecticide and Miticide Use on Grapes in Lower Desert Regions of CA, 1999

Material*	**Lb (ai)**	**Acres Treated**	**% Acres Treated**	**Costs**
Bacillus thuringiensis (Various Products)	190	1,850	7.7	$5,858
carbaryl (Sevin)	29	11	>0.1	$202
chlorpyrifos (Lorsban)	2,240	1,363	5.7	$42,388
cryolite (Kryocide, Prokil)	2,170	444	1.9	$5,447
dimethoate (Dimethoate)	481	1,967	8.2	$4,736
fenamiphos (Nemacur)	3,264	2,164	9	$38,124
horticultural oil (Various Products)	25,757	8,281	34.6	$14,166
imidacloprid (Admire, Provado)	1,449	6,597	27.6	$493,443
methomyl (Lannate)	741	1,046	4.4	$16,472
phosmet (Imidan)	154	148	0.6	$1,598
sodium-tetrathiocarbonate (Enzone)	5,377	312	1.3	$16,507

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the Desert Regions is about $26.68

Table 5. Insecticide and Miticide Use in an OP free Pest Management Program with Available Technology for grapes in the Coastal Regions of CA.

Material	**Rate Form/ac**	**#Appl/ Season**	**Pest**	**Notes**
imidacloprid (Provado 75 WP)	1 oz	1/8	GLH BGSS	
Pyridaben (Nexter)	10 oz	1/10	PSM WM	
or				
avermectin (Agri-Mek 0.15 EC)	10 oz			
or				
propargite (Omite 30W)	6 lb			
or				
fenbutatin-oxide (Vendex 50WP)	1 lb			
horticultural oil (Various Products)	1 gal	1/3	PSM/WM GLH/VLH	
Bacillus thuringiensis (Various Products)	1 lb	1/10	WGS, OT, GL	
or				
tebufenozide (Confirm 2F)	1 pt			
or				
Cryolite (Kryocide 96WP)	8 lb			
carbaryl (Sevin 80S)	2.5 lb	1/100	Cutworms	
imidacloprid (Admire 2F)	2 pt	1/8	Mealybugs BGSS	
methomyl (Lannate 90 SP)	1 lb	1/10	thrips	Not to be used bear open waterways
sodium tetrathiocarbonate (Enzone)	30 lb	1/20	Ectoparasitic nematodes	

Table 6. Insecticide and Miticide Use in an OP free Pest Management Program with Available Technology for grapes in southern San Joaquin Valley of CA.

Material	Rate Form/ac	#Appl/ Season	Pest	Notes
imidacloprid (Provado 75 WP)	1 oz	1/2	GLH	
pyridaben (Nexter)	10 oz	1/2	PSM WM	
or				
avermectin (Agri-Mek 0.15 EC)	10 oz			
or				
propargite (Omite 30W)	6 lb			
or				
fenbutatin-oxide (Vendex 50WP)	1 lb			
horticultural oil (Various Products)	1 gal	1/10	PSM/WM GLH/VLH	
Bacillus thuringiensis (Various Products)	1 lb	1	WGS, OLR, GL	
or				
tebufenozide (Confirm 2F)	1 pt			
or				
encapsulated delta endotoxin (MVP II)	2 pt			
or				
cryolite (Kryocide 96WP)	8 lb			
carbaryl (Sevin 80 S)	2.5 lb	1/100	Cutworms	
imidacloprid (Admire 2F)	2 pt	1/10	VM, GM GWSS	
methomyl (Lannate 90 SP)	1 lb	1/10	Thrips	Not to be used bear open waterways
sodium tetrathiocarbonate (Enzone)	30 lb	1/20	Ectoparasitic nematodes	

Table 7. Insecticide and Miticide Use in an OP free Pest Management Program with Available Technology for grapes in San Joaquin and Sacramento Valleys of CA.

Material	Rate Form/ac	#Appl/ Season	Pest	Notes
imidacloprid (Provado 75 WP)	1 oz	1/5	GLH	
pyridaben (Nexter)	10 oz	1/2	PSM WM	
or				
avermectin (Agri-Mek 0.15 EC)	10 oz			
or				
propargite (Omite 30W)	6 lb			
or				
fenbutatin-oxide (Vendex 50WP)	1 lb			
horticultural oil (Various Products)	1 gal	1/5	PSM/WM GLH/VLH	
Bacillus thuringiensis (Various Products)	1 lb	1/2	WGS, OLR, GL	
or				
tebufenozide (Confirm 2F)	1 pt			
or				
encapsulated delta endotoxin(MVP II)	2 pt			
or				
cryolite (Kryocide 96WP)	8 lb			
carbaryl (Sevin 80S)	2.5 lb	1/20	Leafrollers Cutworms	
sodium tetrathiocarbonate (Enzone)	30 lb	1/25	Ectoparasitic nematodes	

Table 8. Insecticide and Miticide Use in an OP free Pest Management Program with Available Technology for grapes in the lower Desert Regions of CA.

Material	Rate Form/ac	#Appl/ Season	Pest	Notes
horticultural oil (Various Products)	1 gal	1/3	VLH	
Bacillus thuringiensis (Various Products)	1 lb	1/10	WGS, OLR, GL	
or				
tebufenozide (Confirm 2F)	1 pt			
or				
Cryolite (Kryocide 96WP)	8 lb			
imidacloprid (Admire 2F)	2 pt	1	VM, GWSS	
methomyl (Lannate 90 SP)	1 lb	1/20	Thrips	
sodium tetrathiocarbonate (Enzone)	30 lb	1/25	Ectoparasitic nematodes	

Table 9. Insecticide and Miticide Use in an OP-free Pest Management Program with Emerging Technology for Grapes in CA.

Material	Rate Form/ac	#Appl/ Season	Pest	Notes
imidacloprid (Provado 75 WP)	1 oz	1/2	GLH, BGSS	
buprofezin (Applaud 70WP)	1/3 lb	1/2	GLH mealybugs	Not registered
pyridaben (Pyramite)	10 oz	1/2	PSM WM	
or				
avermectin (Agri-Mek 0.15 EC)	10 oz			
or				
clofentezine (Apollo)	1/2 pt			Not registered
or				
fenbutatin-oxide (Vendex 50WP)	1 lb			
Bacillus thuringiensis (Various Products)	1.0 lb	1/4	WGS, OT, OLR, GL	
or				
encapsulated delta endotoxin (MVP II)	2 pt			
or				
cryolite (Kryocide 96WP)	8 lb			
or				
tebufenozide (Confirm 2F)	1 pt			
or				
spinosad (Success 2SC)	6 oz			Not registered
horticultural oil (Various Products)	1 gal	1/20	PSM/WM GLH/VLH	
imidacloprid (Admire 2F)	2 pt	1/100	Mealybugs GWSS	The # of applications depends on the spread of GWSS and VM
fenopropathrin (Danitol 2.4 EC)	10 oz	1/100	GWSS	The # of applications depends on the spread of GWSS
or				
cyfluthrin (Baythroid 2)	3 oz.			Under section 18 that expired on 11/01
kaolin clay (Surround)	37 lb	1/100	GWSS	
Boric acid (baits)	1 lb	1	Ants	Not registered
methomyl (Lannate 90 SP)	1 lb	1/12	Thrips	
Sodium tetrathiocarbonate (Enzone)	30 lb	1/20	Ectoparasitic nematodes	

LETTUCE (HEAD AND LEAF)

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California produces over 70% of the head 'Iceberg' lettuce in the United States. Head lettuce is grown on over 140,000 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. Typically head lettuce fields are planted with seeds with about 2% of fields transplanted. Transplanted fields usually mature a month earlier than fields planted with seeds, which may be useful in regards to pest management. High quality standards for head lettuce mean that growers must be inordinately cautious of insect 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.

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 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. The vast majority of leaf lettuce is planted directly from seed. From planting to harvest is about three months depending on climate, region or cultivar. Leaf lettuce is generally produced for fresh market; however, a significant portion of the romaine and butterhead varieties would be processed as packaged salad mixes and shredded for the fast food market. The portion of the crop designated for the processed market, or for export, is subject to increased scrutiny for damage from insect pests. Contamination in the form of frass, insect bodies or feeding damage is unacceptable and would lead to rejection of the crop by the processor and exporter. Rigorous control of insect pests is vital to the production of leaf or head lettuce for either fresh market or processing.

The primary insect pests of lettuce in the coast region include aphids, various lepidopterous larvae, leafminers and occasionally lygus bugs. The primary insect pests of lettuce in the lower desert region include various seedling pests, lepidopterous larval pests and whiteflies. Aphids, lygus bugs and leafminers do not cause economic damage in most years in the lower desert region. The southern San Joaquin Valley can be affected by the full array of insect pests commonly found on lettuce grown in either the coast region or lower desert region with the exception of whiteflies. In most years only low populations of whiteflies occur on fall lettuce crops in the southern San Joaquin Valley, but the threat from transmission of disease by whiteflies often requires control measures on fall lettuce.

Aphid Species Complex:

Green Peach Aphid (GPA), *Myzus persicae*
Potato Aphid (PA), *Macrosiphum euphorbiae*
Lettuce Aphid (LA), *Acyrthosiphon lactucae*
Lettuce Root Aphid (LRA), *Pemphigus bursarius*

Aphids regularly infest both head and leaf lettuce in all growing regions of the state and are one of the key insect pests. On lettuce seedlings, large aphid populations can impair normal growth. However, most damage occurs as direct contamination from aphid bodies and honeydew secretions in the harvested crop. In addition, GPA can also serve as a disease (virus) vector. Beet western yellows, turnip mosaic and lettuce mosaic virus can threaten production in isolated areas throughout the state. Beet western yellows virus can spread very quickly if not controlled. Lettuce mosaic virus is seedborne, but can be spread throughout an area by GPA.

Severe infestations by PA are LA are usually sporadic and tend to be associated with lettuce fields located along the cooler coast regions. Unlike GPA, these aphid species tend to channel deep into lettuce heads making them more difficult to control and the risk of contamination much greater. LRA is an occasional pest in isolated coast growing areas. LRA feeds in dense colonies at the roots of developing lettuce plants. These aphids would spread from the outer rootlets and eventually destroy the root system. Wilting outer leaves is a good first sign that LRA may be a problem. Limited infestations usually lead to soft and underdeveloped lettuce heads. High populations may cause plant death. LRA is always associated with its primary host, the Lombardy poplar. Effective control of LRA requires the removal of poplar trees from surrounding areas (typically ~2 mile radius). Proper watering would maintain moist soils and prevent soil cracking. Soil cracking provides an entry site for these aphids. LRA is very difficult to control once it has become established.

The high quality standards of lettuce prevent several natural enemies of aphids (ladybugs, lacewings, syrphid flies, etc.) from achieving economic control. Beneficial insects found on the marketable produce are considered contaminates and would result in the downgrading of the commodity. Control of aphids therefore has relied on insecticides. A single insecticide application is usually sufficient to maintain populations below economically damaging levels for the season.

Lepidopterous Species Complex:

Beet Armyworm (BAW), *Spodoptera exigua*
Alfalfa Looper (AL), *Autographa californica*
Cabbage Looper (CL), *Trichoplusia ni*
Corn Earworm (CEW), *Heliocoverpa zea*
Tobacco Budworm (TBW), *Heliothis virescens*

There is a number of lepidopterous larval pests that may cause economic damage to both leaf and head lettuce throughout the state. These lepidopterous pests very often require multiple insecticide applications per season to prevent damage. The two most important lepidopterous pests are CL and BAW. CL and BAW can damage lettuce in all growing regions. Two closely related lepidopterous pests of both leaf and head lettuce in the lower desert and southern San Joaquin Valley are CEW and TBW. CEW and TBW are not significant pests in the coast region and are less of a problem on leaf lettuce as compared to head lettuce. AL occurs in the coast area and is not as significant a pest as CL.

Lepidopterous damage depends on the species and stage of development of lettuce plants. Lettuce seedlings are extremely vulnerable to attack from any of these lepidopterous pests. They may consume entire plants or portions of young leaves including the midrib. This can lead to inhibited growth, reduced photosynthetic activity and, if not managed, eventually death of seedling plants. Lettuce can tolerate a fair amount of damage from lepidopterous larval pests after thinning but before heading. The most severe losses would result when feeding occurs throughout the head growth phase. CEW and TBW bore into lettuce heads while CL and AL feed on the exterior portion of the plant. However, as the plant and CL develop, they would move into the developing head or heart of the lettuce. BAW not only feeds on the exterior like CL but also bores into the lettuce head like CEW and TBW. This often leads to contamination from lepidopteran bodies, frass and feeding. This type of damage is unacceptable for either processing or fresh market.

Applications of broad-spectrum insecticides for these and other pests of lettuce may contribute to subsequent population outbreaks of lepidopterous or other pests due to the elimination of beneficials. This is a special concern since beneficial insects can be very important in limiting lepidopterous pest populations. Various parasitic hymenoptera such as *Hyposoter exiguae, Copidosoma truncatellum, Chelonus insularis,* etc, the tachinid fly *Lespesia archippivora*, pirate bugs and bigeyed bugs can all serve to maintain lepidpterous pest populations below their economic threshold if not disrupted. However, beneficial insects found on the marketable produce are considered contaminates and would result in the downgrading of the lettuce. Viruses that kill lepidopterous larval pests are also very important, but they only occasionally occur in the field. Despite the action of beneficial insects, lepidopterous pests usually require multiple insecticide applications to maintain populations below the injury level. While the availability and use of more selective and reduced risk insecticides, e.g. spinosad (Success 2SC), indoxacarb (Avaunt 30WG) and tebufenozide (Confirm 2F) has increased over the past few years, they are in large measure effective only on lepidopterous pests. Growers often apply a single, broad-spectrum insecticide to control two different pests. For example, control of aphids and lepidpterous larvae can be achieved with acephate (Orthene).

Leafminers:

Liriomyza huidebrensis
Liriomyza trifolii
Liriomyza sativae

Leafminers of the genus *Liriomyza* can infest a wide range of vegetable crops including most cole and lettuce crops. Adult leafminers lay eggs within leaves of lettuce plants preferring cotyledons or young true leaves on seedling plants. Leafminer larvae feed between the upper and lower surfaces of the leaf and produce characteristic white "mines." These tiny tunnels begin narrow and broaden as the larvae grow. Heavy leafminer feeding on emerging seedlings may result in stand reduction. Severe infestation may result in complete stand loss. Leafminer feeding reduces plant photosynthetic capacity and these mines may provide an entry site for plant pathogens. The greatest economic damage is a reduction or elimination of the value of harvested heads due to contamination, especially to lettuce for export or packaged salad mixes. Leafminers are important pests in the coast region and in the southern San Joaquin Valley and their populations are increasing throughout the state.

As with lepidopterous larval pests, parasitic hymenoptera, e.g. *Diglyphus begini* may limit leafminer populations. When high populations are present, especially during seedling development, treatment is usually required. Adult leafminer populations can be suppressed through pesticide application, but treatment must be targeted at the larval stage to achieve economic control.

Silverleaf Whitefly (SLW), *Bemisia Argentifloii*

Silverleaf whitefly thrives throughout the lower desert region of California. Since 1991 it has been an important pest of lettuce in the lower desert region and more recently has begun to cause damage to lettuce grown in the southern San Joaquin Valley. SLW develops on cucurbits and cotton. When these crops are harvested in the fall, SLW often disperse to nearby lettuce fields. SLW feed on all stages of lettuce plants and can contribute to contamination, reduced stands, severely stunted growth and disease transmission. Feeding by whiteflies produces a sticky honeydew on the leaves on which a black, sooty mold may develop. The growth of black sooty mold may lead to unmarketable crops. Heavy SLW pressure at the seedling stage would lead to stunted growth and yellowing of heads. SLW also are vectors of lettuce infectious yellows and related viruses. Biological control of SLW by two parasites (*Encarsia spp.* and *Eretmocerus*) or predators such as the *Geocoris* spp., *Chrysoperla* spp. or Delphastus pusillius, may reduce the population but do not provide economic control. Control of SLW has relied on a preventative systemic imidacloprid (Admire) treatment at the time of broccoli planting.

Other Seedling Pests

In addition to leafminers and lepidopterous larvae, other seedling pests can severely damage seedling and may cause complete stand loss. Garden symphylans, springtails, crickets, flea beetles, darkling beetles and various cutworm species (*Agrotis ipsilon*, *Peridroma saucia* and *Feltia subserranea*) can all pose a risk to germinating lettuce seedlings if pest populations are high. Symphylans feed on the roots of both very young and older lettuce plants. This feeding may stunt or even kill lettuce young lettuce plants. However, the damage is usually not significant in older plants. Springtails, flea beetles and darkling beetles would feed directly on lettuce seedlings, especially on the leaves closest to the ground. This feeding damage results in stand reduction, which may require replanting. Springtails, darkling beetles and garden symphylans are usually controlled by a single soil treatment of Diazinon granules either just before or at planting. Springtails and symphylans are associated with soils rich in organic matter and usually reappear in the same areas of a field year after year. Crickets and cutworms are most active at night and can contribute to significant stand loss if their populations are high. Damage is often seen as rows of damaged or dead seedlings. This damage can occur very quickly with the potential for complete stand loss. Cutworms tend to be more of a problem along the coast region whereas crickets tend to be isolated to sprinkler irrigated lettuce fields in the lower desert region. Baits such as carbaryl (Sevin) are used for the control of these pests. Pyrethroid insecticides can also be useful for control of flea beetles, crickets and cutworms.

Current Pest Management Program

Lower Desert Region

The lower desert region (Riverside and Imperial counties) produces about 20% of the head lettuce and 18% of the leaf lettuce. Lettuce is produced during the late fall and winter months. Insect pest control of the late fall lettuce crop is more difficult and require more insecticide applications than the winter crop. The major pests include lepidopterous larvae, whiteflies and various seeding pests. Because of the warm fall and winter temperatures, aphids are not a significant pest.

Control of lepidopterous pests may require five applications per season on head and leaf lettuce (Tables 1 and 2). Methomyl (Lannate), Success, permethrin (Pounce/Ambush), *lambda*-cyhhalothrin (Warrior), *Bacillus thuringiensis* (Bt), esfenvalerate (Asana), cypermethrin (Ammo), tralomethrin (Scout X-TRA), thiodicarb (Larvin) and Orthene were applied in 1999 for control of lepidopterous larvae. Orthene, Asana and Ammo are not registered on leaf lettuce. BAW is the most important lepidopterous pest of lettuce grown in the lower desert region. BAW is more difficult to control than other lepidopterous pests. Except for Orthene on head lettuce, organophosphate (OP) insecticides are not used to control lepidopterous pests in the lower desert region. The small amount of OP insecticides used for leaf or head lettuce in the lower desert region is for seedling pest control and late season aphid control.

SLW can be a serious pest of lettuce in the desert. SLW feed on all stages of lettuce plants and can contribute to contamination, reduced stands, severely stunted growth and disease transmission. Control of SLW relies on a soil application of imidacloprid (Admire) and/or foliar application of imidacloprid (Provado). About 40% of both leaf and head lettuce was treated with imidacloprid in 1999. Lannate, which is also used for lepidopterous pest control, suppresses light SLW populations.

Diazinon granules were used on about 1/3 of the head lettuce and about 1/4 of the leaf lettuce in the lower desert region for seedling pests in 1999. Crickets and other soil insects are occasional but serious pests that can destroy a newly planted lettuce field in a short period. Diazinon granules are effective for most soil pests while pyrethroid insecticides such as Ammo, Asana, Warrior, Pounce, etc. are more effective for cricket, flea beetle and cutworm control. Dimethoate is used for GPA and PA control during the latter part of the season on about 1/3 of the head lettuce and about 1/6 of the leaf lettuce. The use of other OP insecticides on leaf lettuce was very minimal while Orthene was used on about 1/4 of the head lettuce for aphid and lepidopterous larval control. The average insecticide (material) cost per acre treated for the lower desert region is about $107.24 for head lettuce and about $92.27 for leaf lettuce.

Southern San Joaquin Valley

The southern San Joaquin Valley region (chiefly in Kern and Fresno counties) produces about 18% of the head lettuce and 5% of the leaf lettuce. Two crops of lettuce are produced in the southern San Joaquin Valley. One is planted in late summer for harvest in late fall and the other is planted in late fall to early winter for harvest in mid-spring. Insect pest control of the late fall lettuce crop is more difficult and require more insecticide applications than the mid-spring lettuce crop. The major pests include lepidopterous larvae, particularly BAW, leafminers, SLW, aphids (GPA and PA) and various seeding pests. GPA and PA attack the fall crop while GPA attach the spring crop.

Control of lepidopterous pests may require about seven applications per season on head lettuce and about four applications on leaf lettuce (Tables 3 and 4). Lannate, Success, Pounce/Ambush, Ammo, Scout X-TRA, Warrior, Bt, Asana, Larvin and Orthene were applied in 1999 for control of lepidopterous larvae. Orthene, Asana and Ammo are not registered on leaf lettuce. BAW is the most important lepidopterous pest of lettuce grown in the southern San Joaquin Valley region. BAW develops on adjacent crops, particularly cotton. In the fall, BAW disperse to developing lettuce where considerable damage can result in a short period of time. BAW is more difficult to control than other lepidopterous pests. OP insecticides are not used to control lepidopterous pests in the lower desert region.

SLW can be a pest of lettuce in the Kern County but not to the same extent as in the lower desert region. SLW is generally not a significant pest in Fresno County. Control of SLW relies on a soil application of imidacloprid (Admire) and/or foliar application of imidacloprid (Provado). About 37% of the head lettuce was treated with imidacloprid in 1999 while about 90% of the leaf lettuce was treated with imidacloprid. Leafminers are a serious pest of lettuce in the southern San Joaquin Valley particularly in fall harvested lettuce. Leafminers are of little concern in spring harvested lettuce. Control of leafminers in head lettuce relies on abamectin (Agri-Mek). Agri-Mek was applied, on average 1 1/4 times to head lettuce in the southern San Joaquin Valley. However, most of the Agri-Mek is applied to the fall harvested lettuce. Agri-Mek is not registered on leaf lettuce. Leafminers can also be controlled with cyromazine (Trigard). A lower percent of both leaf and head lettuce was treated with Trigard because of plant back and water management restrictions.

Control of seedling pests relied on Diazinon granules, endosulfan (Thiodan) and pyrethroid insecticides. Diazinon was applied to 77% of the head lettuce and all of the leaf lettuce received an application of Diazinon for seedling pest control. Thiodan was applied to about 85% of the head lettuce and all of the leaf lettuce received an application of Thiodan. Dimethoate is used for GPA control during the latter part of the season on about 40% of the head lettuce and about 20% of the leaf lettuce. Besides Diazinon and Dimethoate, no other OP insecticides were used on leaf lettuce in 1999. In head lettuce, Orthene was used on about 70% of the acreage for aphid and lepidopterous larval control. The average insecticide (material) cost per acre treated for the southern San Joaquin Valley region is about $156.24 for head lettuce and about $75.48 for leaf lettuce.

Coast Region

The coast region (Monterey, San Benito, Santa Barbara, Santa Clara, San Luis Obispo and Santa Cruz counties) produces about 60% of the state's head lettuce and 78% of the leaf lettuce. Monterey County produces more lettuce than any other county. Lettuce is produced year around on the coast. Insect pest control intensifies as the season progresses with the late fall crop requiring more insecticide applications than the spring and summer crops. The major pests include aphids, lepidopterous larvae and to a lesser extent, leafminers.

The most widely used insecticides on head lettuce in 1999 were Provado, Orthene and Pounce (Tables 5) while the most used insecticides on leaf lettuce in 1999 were Provado, and Pounce (Tables 6). The most prevalent lepidopterous pest in the coast region is CL, BAW and AL and numerous insecticides applications are required to control these pests. In 1999, lepidopterous pests were controlled with Orthene, Lannate, Success, Pounce/Ambush, Ammo, Scout X-TRA, Warrior, Bt, Asana and Larvin. These insecticides are applied alone or in combination. They are applied about 1 1/4 times to leaf lettuce and about 2 1/2 times to head lettuce. In addition, head lettuce receives about one application of Orthene. Orthene is not registered on leaf lettuce. The Orthene applications also would suppress GPA populations. Aphids are mainly controlled with Admire/Provado and a number of OP insecticides. In leaf lettuce, Admire/Provado are applied about 1 1/2 times with about half an application of dimethoate. In head lettuce, Admire/Provado are applied about 1 time with about half an application of dimethoate, about 3/4 of an application of oxydemeton-methyl (Metasystox-R) and a small amount of disulfoton (Di-Syston).

Diazinon granules were used on about 70% of the head lettuce and about 85% of the leaf lettuce in the coast region for seedling pests in 1999. Diazinon granules are effective for most soil and seedling pests, particularly garden symphlans and springtails. Control of other seedling pests such as cutworm, darking ground beetle and cricket relied on pyrethroid insecticides.

Leafminers are a serious pest of lettuce in the coast region. Control of leafminer in head lettuce relies on Agri-Mek. Agri-Mek was applied to about 60% of the acreage. However, Agri-Mek is not registered on leaf lettuce. Control of leafminer in leaf lettuce would rely on cyromazine (Trigard). However, due to plant-back restriction with cole crops (one year after a Trigard application), only about 3% of leaf lettuce was treated with Trigard in 1999. The average insecticide (material) cost per acre treated for the coast region is about $103.9 for head lettuce and about $79.83 for leaf lettuce.

OP Free – Pest Management Program with Available Technology

The OP free programs below were constructed with currently registered insecticides for immediate implementation and without regard to resistance management consequences. The pest management programs outlined below would prevent significant damage in excess of current levels. A pest management program in head lettuce, without OP insecticides, would rely on pyrethroids (Ammo 2.5EC, Asana XL, Pounce 3.2EC, Capture 2EC, Warrior T and others) and carbamates (Lannate SP and Larvin 3.2F) for lepidopterous and seedling pests (cutworms, e.g. variegated cutworm, *Peridroma saucia*, black cutworm, *Agrotis ipsilon*, crickets, *Gryllinae* spp., flea beetles, *Epitrix hirtipennis*, Garden symphylan, *Scutigerella immaculata* and darkling beetles, *Blaspstinus* spp.), Thiodan 3EC or 50WP for seedling pests and aphids, *Bacillus thuringienesis* (Dipel 2X or others), Confirm 2F, Avaunt 30 DG and Success 2SC for lepidopterous pests, Provado 1.6F or Admire 2F for aphids and whiteflies and Agri-Mek 0.15EC and Trigard for leafminer. However, Agri-Mek 0.15 EC, Ammo 2.5EC, Asana XL are not registered for use on leaf lettuce. The lack of registered products on leaf lettuce should not be a major obstacle in developing an OP free IPM program. There are insecticides registered on leaf lettuce that can easily be substituted for the insecticides that are not registered. Insect control in lettuce is critical and multiple insecticide applications are required to maintain lettuce free of insect contamination. Because of the need to maintain an insect free commodity with high cosmetic standard, integrated pest management options are severely limited in both leaf and head lettuce. In addition, since growers use precision planting practices to reduce hand-thinning costs, control of seedling pests, particularly in the lower desert region and southern San Joaquin Valley, is critical. To establish uniform plant stands, growers use multiple insecticide applications of broad-spectrum pyrethroid and carbamate insecticides to suppress seedling pests.

Lower Desert Region

The major insect pests of both head and leaf lettuce for winter and spring production in the lower desert region are SLW and lepidopterous larvae. Control of seeding pest is also critical in developing uniform stands of seedling plants. Aphids and leafminers are not a major concern in the lower desert region. Applications of Admire for control of SLW would also control aphids. Most fields have a combination of lepidopterous pests with high populations of BAW, CL, AL, CEW and TBW. AL is not a significant lepidopterous pest in the lower desert region and CEW and TBW are less of a problem on leaf lettuce as compared to head lettuce. Control of BAW and CL, which are the major lepidopterous pests of both head and leaf lettuce, would rely on Success 2SC and/or Lannate SP combined with Dipel 2X. Control by parasites and predators is minimal. It is projected that a typical head lettuce field would require about three applications of a pyrethroid insecticide, (Pounce 3.2EC and others), carbamate insecticide (Lannate SP) or naturalyte insecticide (Success 2SC) per acre per season for control of lepidopterous pests and about two applications in a typical leaf lettuce field (Tables 7 and 8). Control of seedling pests would require about three applications of a pyrethroid insecticide (Pounce 3.2EC and others) or carbamate insecticide (Lannate SP) per acre per season in head lettuce and about two applications in leaf lettuce. Control of SLW would rely on a systemic application of Admire 2F at planting. Additional control of SLW would be provided by the pyrethroid applications directed against lepidopterous larvae.

Southern San Joaquin Valley

The major insect pests of both head and leaf lettuce for fall production in the southern San Joaquin Valley are lepidopterous larvae, various seedling pests, leafminers and SLW. However, SLW is not as important in the southern San Joaquin Valley as it is in the lower desert region while *L. trifolii* has increased in importance, particularly in the fall production in the southern San Joaquin Valley. GPA and/or PA can be pests at times and require treatment. Lettuce production in the southern San Joaquin Valley requires multiple insecticide applications to produce an insect free crop. Most fields have a combination of pests at any one time and insecticides directed against one pest would, in many cases, control additional pests species. It is projected that a typical head lettuce field would require about four applications of a pyrethroid insecticide, (Pounce 3.2EC and others), carbamate insecticide (Lannate SP combined with Dipel 2X), Success 2SC, Confirm 2F or Avaunt30 DG per acre per season for control of lepidopterous pests and about two applications in leaf lettuce (Tables 9 and 10). Control of seedling pests would require about three applications of a pyrethroid insecticide (Pounce 3.2EC and others), carbamate insecticide (Lannate SP) or cyclodiene (Thiodan 50WP/3EC) per acre per season in head lettuce fields and about two applications in leaf lettuce. Control of aphids and SLW would rely on a systemic application of Admire 2F at planting. Leafminer would require two or more applications of Agri-Mek 0.15EC or Trigard 75WP per acre on to fall harvested lettuce and few or no applications on spring harvested lettuce. Aphid control can be achieved with Thiodan 50WP/3EC and additional aphid and SLW control can be achieved with Lannate SP, Thiodan 50wp/3EC and Capture 2EC.

Coast Region

The most important insect pests of leaf and head lettuce in the coast region are lepidopterous larvae and aphids with *L. huidrobrensis* becoming more a problem. Seedling pests and SLW are far less important than in the southern San Joaquin Valley and lower region. The lepidopterous larvae are composed of BAW, CL and AL. CEW and TBW are not as economic important along the coast as they are in the lower desert region. The aphid species are composed of GPA, PA, FA, LA and LRA. Control of aphids in head lettuce has relied largely on Metasystox-R, Orthene 75S and to a lessor extent Dimethodate 4EC. Orthene 75S not only controls aphids but also controls lepidopterous larval pests in head lettuce. Orthene 75S is not registered in leaf lettuce. The loss of Orthene would require a combination of insecticides. For example, Provado 1.6F can be used for aphids while Success 2SC can be used for control of lepidopterous larvae. It is projected that a typical head lettuce field would require about four applications of a pyrethroid insecticide, (Pounce 3.2EC and others), carbamate insecticide (Lannate SP combined with Dipel 2X) or naturalyte insecticide (Success 2SC) per acre per season for control of lepidopterous pests and about three applications in leaf lettuce (Tables 11 and 12). Control of aphids would rely on a systemic application of Admire at planting or two applications of Provado 1.6F during the season. Leafminer would require one application of Agri-Mek 0.15EC (head lettuce only) or Trigard 75WP per acre per season. However, limited amounts of Trigard would be applied due to plant-back restrictions with cole crops. Additional aphid control can be achieved with Lannate directed against lepidopterous larvae.

OP Free – Pest Management Program with Emerging Technology

The IPM programs below were constructed with currently registered insecticides and/or insecticides that are anticipated to be registered within four to five years. The intent of the pest management program with emerging technology is to produce a stable long-term program that would allow for much greater impact of beneficial insects and mites on the pest populations. The pest management program would maintain low pest densities over time and prevent large pest density oscillations. The OP free pest management program with emerging technology is very similar to the OP free pest management program with available technology. The major difference is the replacement of the carbamate insecticides (Lannate and Larvin) with reduced risk insecticides [Success, Intrepid, emamectin benzoate (Proclaim) and Avaunt]. In addition, new neonicotinoid insecticides [thiacloprid (Calypso) and acetamiprid (Assail)] are currently under evaluation for both aphid and lepidopterous pest control. Also, If these insecticides prove to be efficacious for both aphid and lepidopterous pests, then they could be a direct replacement for Orthene. It is anticipated that second generation neonicotinoid insecticides would have significant impact on lettuce production in the coast region. Also, Actara and Platinum (both are thiamethoxam and are neonicotinoid insecticides) are near registration for aphid control of leafy vegetables. The pyrethroid insecticides (Pounce, Asana, Ammo, etc) would still be required for control of seedling pests. Only the pyrethroids provide the rapid control needed for the large number of seedling insect pests.

Lower Desert Region

The major insect pests of both head and leaf lettuce for winter and spring production in the lower desert region are SLW and lepidopterous larvae, particularly BAW and CL. Control of seedling pests is also critical in developing uniform stands of seedling plants. Control of SLW would rely on a single application of Admire in both leaf and head lettuce (Tables 13 and 14). Most fields have a combination of lepidopterous pests. However, these pests can be suppressed by a number of currently registered reduced risk insecticides and/or reduced risk insecticides that are anticipated to be registered in the near future. Control of lepidopterous pests in both head and leaf lettuce would rely on Success 2SC, Intrepid 2F, Proclaim 5WDG or Avaunt 30WDG with or without Dipel 2X. It is projected that a typical head lettuce field would require about two applications per acre per season of one of these reduced risk pesticides and about one application in a typical leaf lettuce field. Since rapid mortality is needed with seedling pests and seedling pests are composed of a diverse group of insects including beetles, crickets, cutworms, garden symphylan, etc., the pyrethroid insecticides would be required to suppress these pests. It is projected that control of seedling pests would require about three applications of a pyrethroid insecticide (Pounce 3.2EC and others) per acre per season in head lettuce and about two applications in leaf lettuce.

Southern San Joaquin Valley

The major insect pests of both head and leaf lettuce for fall production in the southern San Joaquin Valley are lepidopterous pests, various seedling pests, leafminers and SLW. However, SLW is not as important a pest in the southern San Joaquin Valley as it is in the lower desert region while *L. trifolii*, has increased in importance. Lettuce production in the southern San Joaquin Valley requires multiple insecticide applications to produce an insect free crop. Control of SLW and aphids would rely on a single application of Admire in both leaf and head lettuce while control of leafminers would rely on a single application of either Agri-Mek or Trigard in head lettuce (Tables 15 and 16). Agri-Mek is not registered on leaf lettuce. Control of lepidopterous pests in head and leaf lettuce would rely on Success 2SC, Confirm 2F or Intrepid 2F, Proclaim 5WDG or Avaunt 30WDG with or without Dipel 2X. It is projected that a typical head lettuce field would require about four to six applications per acre per season of one of these reduced risk pesticides and about three to five applications in a typical leaf lettuce field (Tables

15 and 16). Since rapid mortality is needed with seedling pests and seedling pests are composed of a diverse group of insects including beetles, crickets, cutworms, garden symphylan, etc., the pyrethroid insecticides would be required to suppress these pests. It is projected that control of seedling pests would require about three applications of a pyrethroid insecticide (Pounce 3.2EC and others) per acre per season in head lettuce and about two applications in leaf lettuce.

Coast Region

The most important insect pests of leaf and head lettuce in the coast region are lepidopterous larvae and aphids. Seedling pests are far less important than in the southern San Joaquin Valley and lower dessert regions. However, *L. huidrobrensis* has become a significant pest of coast lettuce and may require control. The OP free pest management program with emerging technology is very similar to the OP free pest management program with available technology. The major difference is an increase in the number of reduced risk insecticides for lepidopterous larvae control and a slight decrease in the number of applications of pyrethroid for seedling pests. Control of aphids would rely on a single application of Admire or Actara or two applications of Provado or Platinum in both leaf and head lettuce while control of leafminers would rely on a single application of either Agri-Mek or Trigard. Thus use of Trigard would require the establishment of a tolerance on cole crops (Tables 17 and 18). Control of lepidopterous pests in head and leaf lettuce would rely on Success 2SC, Intrepid 2F, Proclaim 5WDG or Avaunt 30WDG with or without Dipel 2X. It is projected that a typical head lettuce field would require about three applications per acre per season of one of these reduced risk pesticides and about two applications in a typical leaf lettuce field. Since rapid mortality is needed with seedling pests and seedling pests are composed of a diverse group of insects, the pyrethroid insecticides would be required to suppress these pests. It is projected that control of seedling pests would require about two applications of a pyrethroid insecticide (Pounce 3.2EC and others) per acre per season in head lettuce and about one application in leaf lettuce.

Addendum – Lettuce

A number of products have been registered in lettuce since the economic analysis. These include acetamiprid (Assail), buprofezin (Applaud) and emamectin benzoate (Proclaim). Assail has aphid/whitefly activity as well as some lepidopteran larval activity. Assail will be useful when multiple pests, i.e., aphid/whiteflies and lepidopteran pests, are present simultaneously. Assail may have a significant impact on lettuce production and may be a replacement for acephate (Orthene). However, Assail is not as efficacious for lepidopteran larval control as Orthene. Other reduced risk insecticides may need to be combined with Assail to achieve a high level of lepidopteran larval control. Applaud is active against whiteflies and will compete against Assail and Provado/Admire for market share. Hopefully, this competition will maintain or reduce costs for the neonicotinoid insecticides. Proclaim has lepidopteran larval activity and will be added to the existing reduced risk insecticides, e.g., tebufenozide (Confirm), indoxacarb (Avaunt), spinosad (Success) and *Bacillus thuringiensis* (various products). The registration of these products will increase the number of available insecticides and hopefully reduce costs.

Table 1. Insecticide and Miticide Use on Head Lettuce in the Desert Region of CA, 1999

Material*	**Lb (ai)**	**Acres Treated**	**% Acres Treated**	**Costs**
acephate (Orthene)	5,412	8,400	24.1	$108,240
abamectin (Agri-Mek)	1	399	1.2	$3,002
azadirachtin (Neemix)	<1	122	0.4	$353
Bacillas thuringiensis. (Various Products)	392	10,948	31.4	$12,102
carbaryl (Sevin)	555	422	1.2	$3,861
clarified neem oil (Triology)	1,054	1,604	4.6	$2,108
cypermethrin (Ammo)	1,021	12,599	36.2	$118,471
diazinon (Diazinon)	9,580	11,739	33.7	$88,523
dimethoate (Dimethoate)	2,998	13,556	38.9	$29,526
disulfoton (Di-Syston)	305	364	1.1	$3,298
endosulfan (Thiodan)	222	330	1	$2,602
esfenvalerate (Asana)	257	6,948	20	$46,728
imidacloprid (Provado, Admire)	3,122	14,077	40.4	$1,062,981
lambda -cyhalothrin (Warrior)	606	25,842	74.2	$254,730
malathion (Malathion)	770	588	1.7	$4,215
methomyl (Lannate)	26,134	39,933	114.7	$580,702
oxydemeton-methyl (Metasystox-R)	99	221	0.6	$3,230
permethrin (Pounce)	3,820	26,605	76.4	$257,843
pyrethrins (Pyrenone)	<1	58	0.2	$480
spinosad (Success)	3,433	45,496	130.6	$1,098,496

tebufenozide (Confirm)	284	2,926	8.4	$26,885
thiodicarb (Larvin)	2,374	4,128	11.9	$8,165
tralomethrin (Scout X-TRA)	60	2,741	7.9	$18,905

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the Desert Regions is about $107.24.

Table 2. Insecticide and Miticide Use on Leaf Lettuce in the Desert Region of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
azadirachtin (Neemix)	15	1,110	6.1	$17,828
Bacillus thuringiensis (Various Products)	308	5,150	28.1	$9,501
clarified neem oil (Trilogy)	665	509	2.8	$1,331
diazinon (diazinon)	3,636	4,086	22.3	$33,596
dimethoate (Dimethoate)	651	2,938	16.1	$6,411
endosulfan (Thiodan)	152	168	0.9	$1,779
imidacloprid (Admire)	1,443	7,435	40.6	$491,445
lambda-cyhalothrin (Warrior)	268	11,663	63.7	$112,762
malathion (Malathion)	42	26	0.1	$230
methomyl (Lannate)	9,084	14,209	77.6	$201,855
permethrin (Pounce)	2,941	19,094	104.3	$198,547
pyrethrins (Pyrenone)	3	182	1	$5,440
spinosad (Success)	1,849	23,404	127.8	$591,686
tebufenozide (Confirm)	135	1,191	6.5	$12,758
thiodicarb (Larvin)	675	1,094	6	$2,321
tralomethrin (Scout X-TRA)	6	278	1.5	$1,808

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the Desert Regions is about $92.27.

Table 3. Insecticide and Miticide Use on Head Lettuce in the Southern San Joaquin Valley of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
acephate (Orthene)	20,303	23,731	67.9	$406,056
abamectin (Agri-Mek)	248	42,261	120.9	$1,241,984
azadirachtin (Neemix)	1	90	0.3	$1,529
Bacillas thuringiensis. (Various Products)	2,837	29,165	83.4	$87,616
carbaryl (Sevin)	3,123	2,208	6.3	$21,738
clarified neem oil (Triology)	698	203	0.6	$1,395
cypermethrin (Ammo)	2,208	23,201	66.4	$256,163
Cyromazine (Trigard)	517	4,791	13.7	$132,454
diazinon (Diazinon)	12,446	26,962	77.1	$115,002
dimethoate (Dimethoate)	3,721	15,248	43.6	$36,651
disulfoton (Di-Syston)	210	125	0.4	$2,270
endosulfan (Thiodan)	25,617	29,659	84.8	$299,722
esfenvalerate (Asana)	123	2,658	7.6	$22,382
imidacloprid (Provado, Admire)	967	12,859	36.8	$329,166
lambda –cyhalothrin (Warrior)	85	3,174	9.1	$35,784
malathion (Malathion)	220	126	0.4	$1,203
methomyl (Lannate)	42,731	52,839	151.1	$949,487
oxydemeton-methyl (Metasystox-R)	266	583	1.7	$8,645
permethrin (Pounce)	5,885	40,472	115.7	$397,251
pyrethrins	1	79	0.2	$960

(Pyrenone)				
spinosad	3,226	39,785	113.8	$1,032,352
(Success)				
tebufenozide	486	3,878	11.1	$45,974
(Confirm)				
thiodicarb	3,969	5,247	15	$13,654
(Larvin)				
tralomethrin	76	3,569	10.2	$24,162
(Scout X-TRA)				

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the Southern San Joaquin Valley is about $156.24.

Table 4. Insecticide and Miticide Use on Leaf Lettuce in the Southern San Joaquin Valley of CA, 1999

Material*	**Lb (ai)**	**Acres Treated**	**% Acres Treated**	**Costs**
azadirachtin (Neemix)	5	1,059	26.1	$5,786
Bacillus thuringiensis (Various Products)	283	2,937	72.3	$8,738
clarified neem oil (Trilogy)	106	103	2.5	$213
cyromazine (Trigard)	36	333	8.2	$9,321
diazinon (diazinon)	2,075	4,169	102.6	$19,169
dimethoate (Dimethoate)	235	901	22.2	$2,310
endosulfan (Thiodan)	3,881	4,380	107.8	$45,413
imidacloprid (Admire)	299	3,626	89.3	$101,950
lambda-cyhalothrin (Warrior)	4	134	3.3	$1,537
methomyl (Lannate)	1,426	2,199	54.1	$31,687
permethrin (Pounce)	767	5,529	136.1	$51,777
pyrethrins (Pyrenone)	4	678	16.7	$7,088
spinosad (Success)	49	578	14.2	$15,571
tebufenozide (Confirm)	10	75	1.9	$900
thiodicarb (Larvin)	38	56	1.4	$129
tralomethrin (Scout X-TRA)	16	761	18.7	$5,079

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the Southern San Joaquin Valley is about $75.48

Table 5. Insecticide and Miticide Use on Head Lettuce in the Coast Region of CA, 1999

Material*	**Lb (ai)**	**Acres Treated**	**% Acres Treated**	**Costs**
acephate (Orthene)	95,805	110,789	98.5	$1,916,096
abamectin (Agri-Mek)	188	23,095	20.5	$940,252
azadirachtin (Neemix)	31	4,123	3.7	$36,926
Bacillas thuringiensis. (Various Products)	1,994	9,068	8.1	$61,575
carbaryl (Sevin)	1,684	393	0.4	$11,719
clarified neem oil (Triology)	178	73	0.1	$356
cypermethrin (Ammo)	2,276	27,992	24.9	$263,981
Cyromazine (Trigard)	120	1,003	0.9	$30,797
diazinon (Diazinon)	46,314	77,748	69.1	$427,941
dimethoate (Dimethoate)	16,256	66,624	59.2	$160,118
disulfoton (Di-Syston)	5,834	3,322	3	$63,004
endosulfan (Thiodan)	2,083	2,309	2.1	$24,366
esfenvalerate (Asana)	213	5,362	4.8	$38,782
imidacloprid (Admire, Provado)	10,442	106,296	94.5	$3,555,351
lambda -cyhalothrin (Warrior)	670	27,466	24.4	$281,400
malathion (Malathion)	28,959	17,091	15.2	$158,405
methomyl (Lannate)	27,973	41,230	36.7	$621,569
oxydemeton-methyl (Metasystox-R)	39,173	80,152	71.3	$1,273,132
permethrin (Pounce)	11,490	89,366	79.4	$775,589
pyrethrins	52	4,610	4.1	$84,000

(Pyrenone)				
spinosad	2,536	44,489	30.7	$811,584
(Success)				
tebufenozide	730	5,996	5.3	$68,985
(Confirm)				
thiodicarb	1,034	1,662	1.5	$3,555
(Larvin)				
tralomethrin	252	10,968	9.8	$79,706
(Scout X-TRA)				

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the Coast Region is about $103.90.

Table 6. Insecticide and Miticide Use on Leaf Lettuce in the Coast Region of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
azadirachtin (Neemix)	124	13,812	18.1	$145,918
Bacillus thuringiensis (Various Products)	1,046	8,206	10.7	$32,287
clarified neem oil (Triology)	1,155	567	0.8	$2,310
cyromazine (Trigard)	249	2,030	2.7	$63,798
diazinon (Diazinon)	41,179	65,624	85.8	$380,492
dimethoate (Dimethoate)	9,761	40,050	52.4	$96,144
endosulfan (Thiodan)	3,130	3,247	4.3	$36,626
imidacloprid (Admire, Provado)	9,082	113,803	148.8	$3,092,210
lambda-cyhalothrin (Warrior)	415	16,357	21.4	$174,094
malathion (Malathion)	14,965	7,756	10.1	$81,857
methomyl (Lannate)	23,282	36,504	47.7	$517,324
permethrin (Pounce)	9,912	74,828	97.9	$397,251
pyrethrins (Pyrenone)	116	8,884	11.6	$185,440
spinosad (Success)	1,557	22,718	29.7	$498,227
tebufenozide (Confirm)	351	2,867	3.8	$33,130
thiodicarb (Larvin)	952	1,667	2.2	$3,276
tralomethrin (Scout X-TRA)	288	12,628	16.5	$91,214

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the Coast Region is about $79.83.

Table 7. Insecticide Use in an OP free Pest Management Program with Available Technology on Head Lettuce in the Lower Desert for Winter Production

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
esfenvalerate (Asana XL)	1/2 pt	3	Lepidopterous larvae and seedling pests	May disrupt biological control
or				
permethrin (Pounce 3.2 EC)	1/4 pt			
or				
lambda-cyhalothrin (Warrior T)	1/8 pt			
or				
cypermethrin (Amno 2.5EC)	1/4 pt			
or				
tralomethrin (Scout X-TRA)	3/16 pt			
methomyl (Lannate SP)	1 lb	2	Lepidopterous larvae and aphids	May disrupt biological control
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1/3	Lepidopterous larvae	
spinosad (Success 2SC)	1/2 pt	1	BAW and other Lepidopterous larvae	
or				
indoxacarb (Avaunt 30 WDG)	1/4 lb			
or				
tebufenozide (Confirm 2F)	1/2 pt			
imidacloprid (Admire 2F)	1 pt	1	Whiteflies and aphids	

Table 8. Insecticide Use in an OP free Pest Management Program with Available Technology on Leaf Lettuce in the Lower Desert for Winter Production

Material	**Rate Form/ac**	**# Appl./ Season**	**Pest**	**Notes**
permethrin (Pounce 3.2 EC)	1/4 pt	2	Lepidopterous larvae and seedling pests	May disrupt biological control
or				
lambda-cyhalothrin (Warrior T)	1/8 pt			
or				
tralomethrin (Scout X-TRA)	3/16 pt			
methomyl (Lannate SP)	1 lb	3/4	Lepidopterous larvae and aphids	
spinosad (Success 2SC)	1/2 pt	1	BAW and other Lepidopterous larvae	
or				
indoxacarb (Avaunt 30 WDG)	1/4 lb			
or				
tebufenozide (Confirm 2F)	1/2 pt			
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1/2	Lepidopterous larvae	
imidacloprid (Admire 2F)	1 pt	1	Aphids and whiteflies	
or				
(Provado 1.6F)	1/4 pt	2		

Table 9. Insecticide Use in an OP free Pest Management Program with Available Technology on Head Lettuce in the Southern San Joaquin Valley for Fall Production

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
esfenvalerate (Asana XL)	1/2 pt	3	Lepidopterous larvae and seedling pests	May disrupt biological control
or permethrin (Pounce 3.2 EC)	1/4 pt			
or lambda-cyhalothrin (Warrior T)	1/8 pt			
or cypermethrin (Amno 2.5EC)	1/8 pt			
or tralomethrin (Scout X-TRA)	3/16 pt			
abamectin (Agri-Mek 0.15EC)	2/3 pt	1	Leafminers, and spidermites	
or cyromazine (Trigard 75WP)	1/6 lb	1	Leafminers	
methomyl (Lannate SP)	1 lb	2	Lepidopterous larvae and aphids	May disrupt biological control
spinosad (Success 2SC)	1/2 pt	1	BAW and other Lepidopterous larvae	
or indoxacarb (Avaunt 30 WDG)	1/4 lb			
or tebufenozide (Confirm 2F)	1/2 pt			
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1/2	Lepidopterous larvae	
endosulfan (Thiodan 3EC)	1/2 pt	1/2	Lepidopterous larvae, aphids and seedling pests	
imidacloprid (Admire 2F)	1 pt	1	Aphids and whiteflies	

Table 10. Insecticide Use in an OP free Pest Management Program with Available Technology on Leaf Lettuce in the Southern San Joaquin Valley for Fall Production

Material	**Rate Form/ac**	**# Appl./ Season**	**Pest**	**Notes**
permethrin (Pounce 3.2 EC)	1/4 pt	1	Lepidopterous larvae and seedling pests	May disrupt biological control
or				
lambda-cyhalothrin (Warrior T)	1/8 pt			
or				
tralomethrin (Scout X-TRA)	3/16 pt			
methomyl (Lannate SP)	1 lb	1	Lepidopterous larvae and aphids	May disrupt biological control
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1/2	Lepidopterous larvae	
spinosad (Success 2SC)	1/2 pt	1	BAW and other Lepidopterous larvae	
or				
indoxacarb (Avaunt 30 WDG)	1/4 lb			
or				
tebufenozide (Confirm 2F)	1/2 pt			
cyromazine (Trigard 75WP)	1/6 lb	1	Leafminers	
endosulfan (Thiodan 3EC)	1/2 pt	1/2	Lepidopterous larvae, aphids and seedling pests	
imidacloprid (Admire 2F)	1 pt	1	Aphids and whiteflies	

Table 11. Insecticide Use in an OP free Pest Management Program with Available Technology on Head Lettuce in the Coast Region for Spring through Fall Production

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
esfenvalerate (Asana XL)	1/2 pt	3	Lepidopterous larvae and seedling pests	May disrupt biological control
or				
permethrin (Pounce 3.2 EC)	1/4 pt			
or				
lambda-cyhalothrin (Warrior T)	1/8 pt			
or				
cypermethrin (Amno 2.5EC)	1/4 pt			
or				
tralomethrin (Scout X-TRA)	3/16 pt			
abamectin (Agri-Mek 0.15EC)	2/3 pt	1/5	Leafminers and spidermites	
methomyl (Lannate SP)	1 lb	1	Lepidopterous larvae and aphids	May disrupt biological control
spinosad (Success 2SC)	1/2 pt	1/2	Lepidopterous larvae	
or				
indoxacarb (Avaunt 30 WDG)	1/4 lb			
or				
tebufenozide (Confirm 2F)	1/2 pt			
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1/4	Lepidopterous larvae	
imidacloprid (Admire 2F)	1 pt	1	Aphids	
or				
(Provado 1.6 F)	1/4 pt	2		

Table 12. Insecticide Use in an OP free Pest Management Program with Available Technology on Leaf Lettuce in the Coast Region for Spring through Fall Production

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
permethrin (Pounce 3.2 EC)	1/4 pt	3	Lepidopterous larvae and seedling pests	May disrupt biological control
or				
lambda-cyhalothrin (Warrior T)	1/8 pt			
or				
tralomethrin (Scout X-TRA)	3/16 pt			
methomyl (Lannate SP)	1 lb	1/2	Lepidopterous larvae and aphids	May disrupt biological control
spinosad (Success 2SC)	1/2 pt	1/4	Lepidopterous larvae	
or				
indoxacarb (Avaunt 30 WDG)	1/4 lb			
or				
tebufenozide (Confirm 2F)	1/2 pt			
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1/4	Lepidopterous larvae	
cyromazine (Trigard 75WP)	1/6 lb	1/3	Leafminers	Use may be limited plant-back problems
imidacloprid (Admire 2F)	1 pt	1	Aphids	
or				
(Provado 1.6 F)	1/4 pt	2		

Table 13. Insecticide Use in an OP Free Pest Management Program with Emerging Technology on Head lettuce in the Lower Desert for Winter Production

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
spinosad (Success 2SC)	1/2 pt	2	Lepidopterous larvae	
or				
indoxacarb (Avaunt 30 WDG)	1/4 lb			
or				
tebufenozide (Confirm 2F)	1/2 pt			
or				
methoxyfenozide (Intrepid 2F)	1/2 pt			Not registered
or				
emamectin benzoate (Proclaim 5WDG)	1/4 pt			Not registered
Bacillus thuringiensis (Dipel 2X)	1 lb	1	Lepidopterous larvae	
imidacloprid (Admire 2F)	1 pt	1	Aphids and whiteflies	
or				
thiamethoxam (Platinum)	1/2	1	Aphids and whiteflies	
esfenvalerate (Asana XL)	1/2 pt	3	Seedling pests	May disrupt biological control
or				
lambda-cyhalothrin (Warrior T)	1/8 pt			
or				
cypermethrin (Amno 2.5EC)	1/4 pt			
or				
tralomethrin (Scout X-TRA)	3/16 pt			
or				
permethrin (Pounce 3.2 EC)	1/4 pt			

Table 14. Insecticide Use in an OP Free Pest Management Program with Emerging Technology on Leaf lettuce in the Lower Desert for Winter Production

Material	**Rate Form/ac**	**# Appl./ Season**	**Pest**	**Notes**
spinosad (Success 2SC)	1/2 pt	2	Lepidopterous larvae	
or				
indoxacarb (Avaunt 30 WDG)	1/4 lb			
or				
tebufenozide (Confirm 2F)	1/2 pt			
or				
methoxyfenozide (Intrepid 2F)	1/2 pt			Not registered
or				
emamectin benzoate (Proclaim 5WDG)	1/4 pt			Not registered
Bacillus thuringiensis (Dipel 2X)	1 lb	2	Lepidopterous larvae	
imidacloprid (Admire 2F)	1 pt	1	Aphids and whiteflies	
or				
thiamethoxam (Platinum)	1/2	1	Aphids and whiteflies	
lambda-cyhalothrin (Warrior T)	1/8 pt	2	Seedling pests	May disrupt biological control
or				
tralomethrin (Scout X-TRA)	3/16 pt			
or				
permethrin (Pounce 3.2 EC)	1/4 pt			

Table 15. Insecticide Use in an OP Free Pest Management Program with Emerging Technology on Head lettuce in the Southern San Joaquin Valley for Fall Production

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
spinosad (Success 2SC	1/2 pt	3	Lepidopterous larvae	
or				
indoxacarb (Avaunt 30 WDG)	1/4 lb			
or				
tebufenozide (Confirm 2F)	1/2 pt			
or				
methoxyfenozide (Intrepid 2F)	1/2 pt			Not registered
or				
emamectin benzoate (Proclaim 5WDG)	1/4 pt			Not registered
or				
indoxacarb (Avaunt 30 WDG)	1/4 lb			Not registered
Bacillus thuringiensis (Dipel 2X)	1 lb	1	Lepidopterous larvae	
imidacloprid (Admire 2F)	1 pt	1	Aphids and whiteflies	
or				
thiamethoxam (Platinum)	1/2	1	Aphids and whiteflies	
abamectin (Agri-Mek 0.15EC)	2/3 pt	1	Leafminers and spidermites	
or				
cyromazine (Trigard 75WP)	1/6 lb	1	Leafminers	
esfenvalerate (Asana XL)	1/2 pt	4	Seedling pests	May disrupt biological control
or				
lambda-cyhalothrin (Warrior T)	1/8 pt			
or				
cypermethrin (Amno 2.5EC)	1/4 pt			
or				
tralomethrin (Scout X-TRA)	3/16 pt			
or				
permethrin (Pounce 3.2 EC	1/4 pt			

Table 16. Insecticide Use in an OP Free Pest Management Program with Emerging Technology on Leaf lettuce in the Southern San Joaquin Valley for Fall Production

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
spinosad (Success 2SC)	1/2 pt	2	Lepidopterous larvae	
or				
indoxacarb (Avaunt 30 WDG)	1/4 lb			
or				
tebufenozide (Confirm 2F)	1/2 pt			
or				
methoxyfenozide (Intrepid 2F)	1/2 pt			Not registered
or				
emamectin benzoate (Proclaim 5WDG)	1/4 pt			Not registered
Bacillus thuringiensis (Dipel 2X)	1 lb	1	Lepidopterous larvae	
imidacloprid (Admire 2F)	1 pt	1	Aphids and whiteflies	
or				
thiamethoxam (Platinum)	1/2	1	Aphids and whiteflies	
lambda-cyhalothrin (Warrior T)	1/8 pt	2	Seedling pests	May disrupt biological control
or				
cypermethrin (Amno 2.5EC)	1/4 pt			
or				
tralomethrin (Scout X-TRA)	3/16 pt			
or				
permethrin (Pounce 3.2 EC	1/4 pt			

Table 17. Insecticide Use in an OP Free Pest Management Program with Emerging Technology on Head lettuce in the Coast Region for Spring through Fall Production

Material	**Rate Form/ac**	**# Appl./ Season**	**Pest**	**Notes**
spinosad (Success 2SC	1/2 pt	2	Lepidopterous larvae	
or				
indoxacarb (Avaunt 30 WDG)	1/4 lb			
or				
tebufenozide (Confirm 2F)				
or				
methoxyfenozide (Intrepid 2F)	1/2 pt			Not registered
or				
emamectin benzoate (Proclaim 5WDG)	1/4 pt			Not registered
Bacillus thuringiensis (Dipel 2X)	1 lb	1	Lepidopterous larvae	
abamectin (Agri-Mek 0.15EC)	2/3 pt	1/3	Leafminers and spidermites	
or				
cyromazine (Trigard 75WP)	1/6 lb	1/3	Leafminers	
esfenvalerate (Asana XL)	1/2 pt	2	Seedling pests	May disrupt biological control
or				
lambda-cyhalothrin (Warrior T)	1/8 pt			
or				
cypermethrin (Amno 2.5EC)	1/4 pt			
or				
tralomethrin (Scout X-TRA)	3/16 pt			
or				
permethrin (Pounce 3.2 EC	1/4 pt			
imidacloprid (Admire 2F)	1 pt	1	Aphids and Whiteflies	
or				
thiamethoxam (Platinum)	1/2pt	1		
or				
imidacloprid (Provado 1.6F)	1/4 pt	2		
or				
thiamethoxam (Actara)	1/4 lb	2		

Table 18. Insecticide Use in an OP Free Pest Management Program with Emerging Technology on Leaf lettuce in the Coast Region for Spring through Fall Production

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
spinosad (Success 2SC)	1/2 pt	1	Lepidopterous larvae	
or				
indoxacarb (Avaunt 30 WDG)	1/4 lb			
or				
tebufenozide (Confirm 2F)	1/2 pt			
or				
methoxyfenozide (Intrepid 2F)	1/2 pt			Not registered
or				
emamectin benzoate (Proclaim 5WDG)	1/4 pt			Not registered
Bacillus thuringiensis (Dipel 2X)	1 lb1		Lepidopterous larvae	
lambda-cyhalothrin (Warrior T)	1/8 pt	1	Seedling Pests	May disrupt biological control
or				
cypermethrin (Amno 2.5EC)	1/4 pt			
or				
tralomethrin (Scout X-TRA)	3/16 pt			
or				
permethrin (Pounce 3.2 EC	1/4 pt			
imidacloprid (Admire 2F)	1 pt	1	Aphids and Whiteflies	
or				
thiamethoxam (Platinum)	1/2pt	1		
or				
imidacloprid (Provado 1.6F)	1/4 pt	2		
or				
thiamethoxam (Actara)	1/4 lb	2		

ORANGES

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There are four major citrus growing regions in the state: southern interior (Los Angeles, Orange, San Diego, San Bernardino and Riverside counties), southern coastal (Ventura, Santa Barbara and San Luis Obispo counties), desert (Coachella and Imperial valleys) and the San Joaquin Valley (Madera, Fresno, Tulare and Kern counties). The climate of these regions and the varieties of citrus grown influence the pest problems that they experience. Lemons are the primary crop grown on the coast, grapefruit is the primary crop grown in the desert while navel and Valencia oranges are the primary crops grown in the southern interior and the San Joaquin Valley. California navel and Valencia oranges are grown for fresh market where cosmetic appeal is extremely important. Biological control is the primary method of pest management for oranges grown in the southern coastal and interior valleys because of the moderate and fairly uniform temperatures throughout the year. Pesticide use is relatively minor in these areas. In the San Joaquin Valley, however, the extremes of summer heat and winter cold reduce the effectiveness of natural enemies. Because of the reduced effectiveness of natural enemies, organophosphate (OP) and carbamate insecticides have been, until recently, the primary method of pest management in this region.

San Joaquin Valley

The key insect pests of San Joaquin Valley oranges have traditionally been citrus thrips and California red scale. In response to these pests, growers have, for more than 40 years, sprayed OP and carbamate insecticides one to three times per year. Because of the long period of use of OP and carbamate insecticides, resistance has developed in many populations of citrus thrips and California red scale. Resistance has not caused complete failure of the insecticides. Instead, insecticide resistance has reduced the length of time that the insecticides are effective, requiring growers to apply insecticides more frequently. Because of the expense of multiple treatments and the lack of efficacy of those treatments due to resistance, growers recently shifted their pest management practices away from OP and carbamate use. A portion of the growers now rely more heavily on natural enemies, while others have begun to use newly registered reduced risk insecticides such as spinosad (Success), pyriproxifen (Esteem) and buprofezin (Applaud). Applaud (section 18 registration 1997-1999) and Esteem (section 18 registration 1998-1999 and full registration as of 2000) are insect growth regulator (IGR) insecticides that have little or no mammalian toxicity. The reduction of OP and carbamate insecticide use has resulted in increasing damage from other insect pests that were previously controlled by these pesticides. Katydids, various ant species and citricola scale, are not effectively controlled by the newly registered reduced risk insecticides nor by natural enemies, particularly in the San Joaquin Valley. In addition, the shift to the IGR insecticides has created cottony cushion scale problems because the predatory vedalia beetle is very sensitive to these new insecticides.

Citrus Thrips (CT), *Scitothrips citri*

Citrus thrips feed at the top of the newly developing fruit and cause a permanent ringlike scar on the surface of the fruit. Growers have a very low tolerance for this pest because populations can cause economic damage to new fruit within just a few days. Because it is sometimes difficult to schedule a pesticide application with such short notice or cover the entire citrus acreage in a timely fashion, growers tend to begin spraying as soon as CT immatures begin to emerge on the new fruit. The predatory mite, *Euseius tularensis*, is a generalist predator that feeds on CT. However, because *E. tularensis* does not feed exclusively on CT, it does not always reduce the number of CT below damaging levels.

Control of CT has relied on repeated applications of a number of broad-spectrum OP and carbamate insecticides. The repeated use of these insecticides resulted in the development of resistance in the early 1980's. While these insecticides will still control some CT populations, resistance reduces the length of time the insecticides are effective. To compensate for lower efficacy, growers apply the pesticides more frequently. Use of the OP insecticide dimethoate (Dimethoate) and the carbamate insecticide formetanate hydrochloride (Carzol) peaked during 1992 then declined during the years following. Two factors stimulated the decline in use. The first was the introduction of cyfluthrin (Baythroid), a new pyrethroid insecticide that was more effective than the OP and carbamate insecticides in orange groves where CT resistance was a problem. Secondly, the densities of CT declined, in part because of changing weather conditions. Wet springs result in greater mortality of CT pupae. Baythroid resistance was documented in some areas of the San Joaquin Valley in the mid to late 1990's. During the 1980's and 1990's, a number of growers wishing to reduce broad-spectrum pesticide use applied sabadilla (Veratran D) mixed with sugar or molasses. Unfortunately, control of CT with this product was sometimes less than satisfactory, requiring multiple applications. Abamectin (Agri-Mek) and Success, each combined with a low rate of narrow range oil, were introduced for CT control in the mid to late 1990's and, due to their greater efficacy, have replaced much of the Veratran use. Success is rapidly replacing Baythroid use in areas where Baythroid resistance is a problem. Agri-Mek use is limited because of expense, making Success and Baythroid the primary methods of CT control. The pyrethroid, fenpropathrin (Danitol) received full registration for citrus in 2001 and Danitol will be a substitute for Baythroid.

California Red Scale (CRS), *Aonidiella aurantii*

California red scale is the major armored scale pest of citrus. CRS infests citrus fruit, leaves and twigs and can cause dieback of branches if population densities are high. CRS is kept under adequate control in the coastal and interior regions of southern California by two parasitoids, *Aphytis melinus* and *Comperiella bifasciata*, as well as generalist predators. However, in the San Joaquin Valley, cold winters synchronize stages of CRS so that in the late spring suitable stages for parasitism by *A. melinus* and *C. bifasciata* are not available. In addition, the hot summers of the San Joaquin Valley cause rapid increases of CRS populations and hinder parasitism by *A. melinus*. Approximately 20% of growers in the San Joaquin Valley release *A. melinus* wasps for control of CRS. If CRS populations are high, a summer application of 415 oil is be applied to suppress the populations. Due to the uncertainty of the level of success of biological control, the majority of citrus growers tend to rely upon chemical control to keep CRS populations below an economically injurious level. Because of repeated insecticide applications over a number of years, CRS populations in the San Joaquin Valley have developed resistance to the OP insecticides chlorpyrifos (Lorsban) and methidathion (Supracide) and the carbamate insecticide carbaryl (Sevin). These insecticides have been replaced primarily with the IGR insecticide Esteem. During 1998-99 Applaud was applied to approximately 7% of the acreage for CRS control in the San Joaquin Valley. Esteem has been so effective against CRS that growers need only treat once every 2-3 years and this has greatly reduced the use of OP insecticides.

Forktailed Katydids (FK), *Scudderia furcata*

Forktailed katydids have historically been considered only sporadic pests of oranges. FK are extremely sensitive to OP insecticides. They are easily killed by a rate of Lorsban that is 1/100 lower than the rate used for CRS and 1/10 lower than the rate used for CT. Thus, OP insecticides used to control CT or CRS have incidentally controlled FK. However, as OP and carbamate insecticides for CT and CRS have been replaced with reduced risk insecticides (Success and Esteem), FK have become a severe problem in a number of orange groves. Most damage occurs near petal fall, when FK feed on the rind of newly forming fruit. If the fruit does not abort, the scar is retained and the fruit is downgraded. Most frequently the chewing mark FK make in the rind results in a quarter-sized scar in the rind at harvest time. Success or cryolite (Kryocide/Prokil) can provide good control of very young FK. These short residual insecticides are not very effective if the nymphs are later instars or the hatch of nymphs is prolonged. Growers that use broad-spectrum insecticides such as Baythroid or Danitol for CT will also control FK, since the two pests are present at the same time of year. However, these insecticides are quite toxic to the natural enemies. Growers that want to preserve natural enemies, but get quick and effective kill of FK, use a very low rate of Lorsban (a few ounces per acre). Many of the key San Joaquin Valley natural enemies, notably *A. melinus, C. comperiella* and *E. tularensis*, have developed resistance to Lorsban. The loss of OP insecticides such as Lorsban will make control of secondary pests such as FK in oranges groves more difficult and costly. This is because newer insecticides are more expensive, sometimes less selective, and may not be as effective in controlling katydid as Lorsban.

Citricola Scale (CS), *Coccus pseudomagnolarum*

Citricola scale infestations reduce tree vigor and heavy infestations can severely reduce yield. Further, sooty mold will develop on the honeydew excreted in the springtime. Large amounts of sooty mold may result in downgrading of the fruit. Biological control by various *Metaphycus* wasp parasites of CS has been very effective in southern California. In southern California, alternate multiple generation hosts, such as black scale and soft brown scale, provide suitable stages for parasitism at all times of year. In the San Joaquin Valley, these alternate hosts are less abundant and biological control agents generally do not control CS well enough to prevent economic damage. This pest is univoltine and stages of CS that are appropriate for parasitism by *Metaphycus* are only available in the late fall and early spring, which does not give the parasites enough time to get the population under control. Where growers continue to use OP or carbamate insecticides for CT or CRS, CS is not a problem because of its sensitivity to these insecticides (easilty controlled with 1/5-1/10 the rate used for CRS). Unfortunately, CS is unaffected by the selective CT insecticides (Veratran, Success or Agri-Mek) or the selective CRS insecticide

Esteem. CS can be controlled with imidacloprid (Provado/Admire), however these insecticides are toxic to vedalia beetles and their use may result in cottony cushion scale outbreaks. The current best control tactic for CS is the use of a low rate of Lorsban (2 pints/acre) because the key San Joaquin Valley natural enemies have developed resistance to OP insecticides, especially Lorsban. The loss of OP insecticides such as Lorsban will make control of secondary pests such as CS in oranges groves more difficult and costly. The new insecticides are more expensive than OP insecticides and if vedalia beetle is disrupted, and OP insecticides are not available, cottony cushion scale outbreaks will reduce yield of the crop.

Ant complex:

> Argentine Ant (AA), *Iridomyrmex humilis*
> Native Gray Ant (NGA), *Formica aerata*
> Southern Fire Ant (SFA), *Solenopsis xyloni*

Argentine and native gray ants are indirect pests of citrus. These ants feed on the honeydew excreted by soft scales, mealybugs, cottony cushion scales, whiteflies and aphids, and therefore are referred to as sugar-feeding ants. The ants protect these honeydew producing insects from parasitism and significantly interrupt their biological control. In the process of protecting the honeydew producing insect, they also protect CRS from parasitism even though CRS does not produce honeydew. Since AA and NGA prevent natural enemies from controlling CRS, and because biological control of CRS is the preferred management option particularly in southern California, AA is considered a significant pest. Growers spot spray the base of trees to prevent ants from hindering biological control. The only effective insecticide registered for sugar-feeding ant control, including AA and NGA, is Lorsban. Lorsban treatments both hinder and help biological control. The Lorsban fumes can kill adult parasites, but the reduction in ant activity allows better parasitism. The loss of Lorsban would directly reduce biological control because there would be no treatment for AA and NGA. SFA can be a severe problem in newly planted orange groves when they feed on the tender bark of the trees. SFA feeding can girdle the tree causing plant death. Currently, abamectin (Clinch Ant Bait) and pyriproxyfen (Esteem Ant Bait) are registered for ant control in citrus. Both abamectin and pyriproxyfen are reduced risk IGR insecticides. However, these baits are only attractive to protein-feeding SFA. They are not effective against sugar-feeding ants (AA and NGA). In the San Joaquin Valley, SFA and NGA are the most common ant species found in citrus.

Citrus Red Mite (CRM), *Panonychus citri*

Citrus red mite was once considered a primary pest of citrus. Studies demonstrated that even very high populations only slightly reduce yield and the treatment threshold was increased from four to eight adult females per leaf. CRM is only an occasional pest in the San Joaquin Valley. Population increases are observed in the spring following broad-spectrum (OP, carbamate, pyrethroid) insecticide application or due to weather conditions such as mild winters and summers. CRM populations collapse in the early summer when temperatures exceed 90ºF and a virus epidemic is initiated. CRM damages citrus by stippling the leaves and fruit, and may cause leaf drop when densities are very high. The majority of growers simply increase the amount of narrow range oil they would apply (from 0.5% to 1.5%) with a Success or Agri-Mek treatment for their CT control. In this way, they avoid a separate treatment for CRM. Some growers treat in the fall or spring with a miticide such as dicofol (Kelthane), fenbutatin oxide (Vendex), propargite (Omite) or pyridaben (Nexter).

Lepidopteran Pests

A number of lepidopteran pests can attack oranges. They include citrus cutworm, fruittree leafroller, *Amorbia* and others. These pests damage the fruit when it is first forming by feeding on the rind. Damaged fruit may fall off the tree or the rind may be scarred. Fruittree leafroller will bore through the rind of maturing Valencia fruit. These pests have a number of natural enemies that generally keep population levels low. If populations increase to economic threshold levels, then an application of *Bacillus thuringiensis* (Bt) will be used to suppress the populations. Since Bt is a slow acting stomach poison, Bt must be applied when larvae are young and before serious damage has occurred (before petal fall). If faster action is needed because young fruit are exposed, growers will use methomyl (Lannate) or Lorsban or choose a CT treatment with broad-spectrum activity such as Baythroid.

Cottony Cushion Scale (CCS), *Icerya purchasi*

Cottony cushion scale can quickly and severely reduce the yield of citrus trees. In addition CCS also produces honeydew. The honeydew supports the growth of sooty mold that will coat the leaves and fruit. CCS has been controlled for more than 100 years by the predatory vedalia beetle, *Rodolia cardinalis*. When new insecticide groups such as the OP and carbamate insecticides were first introduced, they reduced populations of this beetle causing outbreaks of CCS. Today, the vedalia beetle has developed excellent levels of resistance to OP insecticides, and survives these applications very well in the San Joaquin Valley. Thus, OP applications for other pests do not disrupt the vedalia beetle's control of CCS. In 1998, Esteem and Applaud (Section 18) were introduced for control of CRS. Both are reduced risk IGR insecticides. Applaud prevents the vedalia beetle larvae from molting and Esteem prevents the eggs from hatching and the pupae from developing into adults. When Esteem and Applaud were introduced for control of CRS, populations of vedalia beetle were severely suppressed in the San Joaquin Valley. Without vedalia beetles to control CCS populations, severe outbreaks resulted. Some growers were required to apply malathion (Malathion) or Supracide for CCS control, thus severely disrupting the other natural enemies in their groves such as *Aphytis*, a parasite of CRS. The problem lessened in subsequent years either because less acreage was treated, or because vedalia beetles are adapting to the new pesticides. However, CCS remains a concern for San Joaquin Valley citrus because the neonicotinoid insecticides (Admire/Provado, Actara and Assail), which are registered or nearing registration for CRS and glassy-winged sharpshooter control, are also very toxic to vedalia beetles. Lacking OP insecticides, Sevin will be the only insecticide available for CCS control if the vedalia beetle continues to be disrupted by the reduced risk insecticides.

Newly Introduced Pests

Glassy-winged Sharpshooter (GWSS), *Homalodiscus coagulata*

San Joaquin Valley pest management is currently in a transition state. Several newly arrived insects, for example the GWSS, have become significant pests. GWSS is not thought to be a serious direct pest of oranges. However, GWSS uses oranges as an oviposition host and citrus can support large numbers of GWSS. GWSS is primarily a pest of grapes because it vectors the Xylella fastidious bacterium that causes Pierce's disease. Thus, orange growers are under great pressure to reduce GWSS numbers. GWSS are not difficult to control with broad-spectrum insecticides and a number of OP, carbamate, pyrethroid and neonicotinoid insecticides are available for control purposes. Until satisfactory biological control of this pest is accomplished or disease resistant grape vines are developed, presence of this pest will severely disrupt the existing integrated pest management program in oranges. Broad spectrum insecticides applied for GWSS are likely to cause outbreaks of CRM and CT because of disruption of predatory mites and outbreaks of CCS because of disruption of vedalia beetles. GWSS is currently infesting only Kern County citrus. Admire is the preferred treatment and applications to approximately 5% of the San Joaquin Valley acreage began in 2000.

Current Pest Management Program

Southern Coastal and Interior Valleys

The southern coastal and interior valleys that include Los Angeles, Orange, San Luis Obispo, Santa Barbara, Ventura and the western portions of San Diego, Riverside and San Bernardino counties has about 30,000 acres of navel and Valencia oranges. The key insect pests are CRS, AA and NGA. CT is not a significant pest in the southern coastal and interior valleys. Control of CRS relies primarily on biological control and narrow range oil applications and secondarily on Lorsban. Ants (AA and NGA) that disrupt biological control of CRS are primarily controlled with low amounts of Lorsban. Lorsban is also used for control of a wide range of other pests including various soft scales, ants, FK and various lepidopteran pests. Lorsban is the primary insecticide used in this region and was applied to about 50% of the acreage (Table 1). In 1999, Success was used on about 4% of the acreage. Success provides good control of CT and good control of FK and lepidopteran pests. Success was registered in 1998 and its use is expected to increase in the future. The use of OP insecticides other than Lorsban is minimal with less than 5% of the acreage treated. The average insecticide (material) cost per acre for orange production in the southern coastal and interior valleys region in 1999 was about $19.

San Joaquin Valley

The San Joaquin Valley citrus growing region that includes Madera, Fresno, Tulare and Kern counties has over 175,000 acres of navel and Valencia oranges. The primary pests are CT, CRS, ants, FK, CS, CRM and GWSS. CCS can be a significant pest when vedalia beetle has been eliminated by IGR or neonicotinoid insecticides. Control of CT relies primarily on the use of Success and Baythroid (Table 2). Success was applied to about 44% of the acreage while Baythroid was applied to about 38% of the acreage. Success has replaced Baythroid in areas where CT has developed resistance to Baythroid. Control of CRS relies primarily on narrow range oil, Esteem, Lorsban, and to a lesser extent, Supracide and Sevin. Approximately 20% of the acreage receives *Aphytis* releases (100,000 wasp/acre applied in 5,000 every two weeks from March through October). Esteem was applied to about 12% of the acreage while Lorsban was applied to about 29% of the acreage. Esteem has been so effective against CRS that growers need only treat once every 2-3 years. Esteem has replaced Lorsban in areas where CRS has developed resistance to Lorsban. Lorsban is used for a number of other pests besides CRS (FK, lepidopteran larvae, ants and CS). FK and CS are extremely sensitive to Lorsban and other OP insecticides and can be controlled with very low rates of Lorsban. FK is incidentally controlled by thrips/lepidopteran treatments of Carzol, Cygon, Baythroid and, to a lesser extent, Success. FK can also be controlled by Kryocide/Prokil. CS is incidentally controlled by CRS treatments of Sevin, Lorsban, Supracide or Admire. AA, NGA and SFA are controlled by spot applications of Lorsban to the base of trees. Clinch or Esteem Ant Bait is used for SFA. Control of various lepidopterous pest, e.g. cutworm, leafrollers, looper and armyworm, relies on Bt products and, to a lesser extent, OP and carbamate insecticides. CRM is controlled by narrow range oil, Nexter, Kelthane, Vendex and Omite. Vedalia beetle controls CCS. However, if vedalia beetle populations are disrupted by IGRs or neonicotinoids, then Malathion, Supracide, or Sevin treatments are needed. GWSS suppression programs in Kern County are utilizing Admire for control of this pest in citrus. The average insecticide (material) cost per acre for orange production in the San Joaquin valley region in 1999 was about $83.

OP Free – Pest Management Program with Available Technology

The OP free pest management programs below were constructed with currently registered insecticides for immediate implementation and without regard to resistance management consequences or cost of the programs.

Southern Coastal and Interior Valleys

Pest control in the southern coastal and interior valleys would rely primarily on biological control supplemented with narrow range and selective insecticides where possible. The key insect pests are CRS, AA and NGA. Control of CRS would rely on narrow range oil and mass release of *Aphytis.* About 1/4 of the acreage would receive an application of narrow range oil and about 1/4 of the acreage would receive releases of *Aphytis* for CRS control (Table 3). Although, CRS populations are held under control by biological control, sugar-feeding ants (AA and NGA) can disrupt the biological control of CRS. AA and NGA protect CRS from parasitization by *Aphytis* for the sugar that CRS produces. AA and NGA are currently held under control with spot treatments of a low rate of Lorsban. If Lorsban is no longer registered for ant control, then the CRS population would be expected to increase because there are no alternative control methods for sugar-feeding ants. To prevent damage due to CRS, some growers would apply Sevin, Esteem or Admire. However, these insecticides will disrupt the biological control of not only CRS but also a number of other insect pests including mites, black scale, cottony cushion scale, mealybugs and others, resulting in increased number of insecticide applications for these pests. With the lack of effective alternative controls for sugar-feeding ants, it is estimated that there would be a 20% increase in scale-infested fruit above current levels in untreated orchards and yield would be drastically reduced (50-80%) in the orchards with heavy populations of CCS. However to prevent damage crchards would be treated with Sevin. Since Sevin is quite toxic to most natural enemies, there would be secondary pest outbreaks and insecticides use would escalate. Growers would return to the pesticide treadmill of treating for one pest, and finding that it caused an outbreak of a secondary pest, then treat for the second pest and so on.

CT is not a significant pest in the southern coastal and interior valleys. CT populations are suppressed by *Euseius.* However, *Euseius* is primarily a predator of CRM and will feed incidentally on CT larvae. About 1/4 of the acreage would be treated with Success, Agri-Mek or possibly Baythroid or Carzol for CT. Success, Baythroid and Carzol along with Kryocide would also suppress FK. CRM is not a significant pest in the southern coastal and interior valleys. CRM populations are suppressed by *Euseius* as well as a virus. Only about 1/10 of the acreage would need to be treated with narrow range oil, Omite, Nexter, Vendex or Kelthane for CRM control. Lepidopteran species are not significant pests in the southern coastal and interior valleys. About 1/10 of the acreage would be treated with Bt, Success or Lannate. Although, there is currently no effective control of sugar-feeding ants, there is effective control for protein-feeding ants (SFA). Control of SFA would rely on Clinch or Esteem Ant Bait and about 1/10 of the acreage would be treated with either of these products. GWSS is infesting this region and it's potential as a direct pest of oranges is currently being studied.

San Joaquin Valley

The key insect pests are CT, CRS, ants, FK, CS, CCS, GWSS and CRM (Table 4). Pest control in the San Joaquin Valley would rely primarily on narrow range oil and the insecticides Success, Baythroid, Sevin, Esteem, Bt, and Admire.

CT populations would be controlled with Success + oil, Baythroid, Danitol, Carzol, or Agri-Mek + oil. Baythroid, Danitol, Carzol, to a lesser extent Success would concurrently control FK. Kryocide/Prokil would also control FK. About 1 and 1/2 applications would be required for CT and FK control. The selection of insecticide would depend on the pest species present and the degree of insecticide resistance in the grove. CT has become resistant to Baythroid and/or Carzol in some orange groves.

Control of CRS would rely on narrow range oil, Esteem, Sevin or Admire and/or the mass release of *Aphytis.* About 1/2 of the acreage would receive an application of Narrow range oil, Esteem, Sevin or Admire and about 1/4 of the acreage would receive the mass release of *Aphytis*. In orange groves with high populations of sugar-feeding ants (AA and NGA) the mass release of *Aphytis* would not be used to control CRS. These orange groves would rely on insecticides for CRS control. AA and NGA protect CRS from parasitization by *Aphytis* for the sugar that CRS produces. The ants would negate to some extent the effectiveness of the mass release of *Aphytis* and there would be no effective registered insecticides for sugar-feeding ants. The reliance on Esteem or Admire for control of CRS could lead to increased damage particularly from CCS because these insecticides are toxic to vedalia beetles. Yield would be drastically reduced (50-80%) in the orchards with heavy populations of CCS or Sevin would be used. Sevin is toxic to predatory mites and parasitic wasps, and so its use would promote secondary pests such as soft scales and mites. Growers who use any of the scale insecticides (except oils) would return to the pesticide treadmill of treating for one pest, and finding that it caused an outbreak of a secondary pest, then treat for the second pest and so on.

Without OP insecticides, CS populations would be treated with broad-spectrum insecticides such as Sevin, or Admire, with the same CCS and mite outbreaks noted for CRS. Provado is also effective against CS but can cause outbreaks of CRS.

Although, there is currently no effective control of sugar-feeding ants, there is chemical control for protein-feeding ants (SFA). Control of SFA would rely on Clinch or Esteem Ant Bait and about 1/4 of the total acreage would be treated with either of these products. Damage to young trees (5% of total acreage) would increase by about 25% because these insecticides do not work quickly enough to prevent SFA feeding on the bark of young trees.

Lepidopteran species are important but not significant pests in the San Joaquin Valley. About 1/4 of the acreage would be treated with Bt, Success or Lannate. About 1/4 of the acreage would be treated with Narrow range oil, Omite, Nexter, Vendex or Kelthane for CRM control in the absence of outbreaks. However, if broad spectrum insecticide use (carbamates, pyrethroids and neonicotinoids) increases for GWSS and scale pests, then mite outbreaks will increase, requiring additional insecticide treatments.

GWSS is a pest only in the southernmost area of the San Joaquin Valley. In the absence of OP insecticides, the carbamate, pyrethroid and especially the neonicotinoid insecticides would be used against this pest. Use of these broad spectrum insecticides would cause CCS, and CRM outbreaks, requiring additional insecticide treatments.

OP Free – Pest Management Program with Emerging Technology

The pest management program below was constructed with currently registered insecticides and/or insecticides that are anticipated to be registered within four to five years. The pest management program with emerging technology is intended to produce a stable, long-term program that would allow for much greater impact of beneficial insects and mites on the pest populations. The pest management program would maintain low pest densities over time and prevent large pest density oscillations. One pest management program with emerging technology was developed for both southern coastal and interior valleys and the San Joaquin Valley. The same pest management system would be implemented in both regions. However, the intensity of the different components of the pest management system would be implemented to different degrees depending on pest pressures. In general, the pest pressures in the southern coastal and interior valleys are less intense than in the San Joaquin Valley.

Pest control would rely primarily on Narrow range oil and selective insecticides (Table 5). The key insect pests are CT, CRS, ants, FK, CS, CCS and GWSS.

CT populations would be controlled with Success, Veratran D, Agri-Mek and to a limited extent the pyrethroids Baythroid and Danitol. Success, the pyrethroid insecticides, along with Kryocide/Prokil would also suppress FK. Control of CT and FK would require about 1/4 to 1 and 1/2 applications depending on region and year. The reduction of broad-spectrum insecticides, e.g. Carzol, Baythroid and Danitol, and the reliance on reduced risk insecticides would allow for greater impact of predators of CT, e.g. *Euseius tularensis*.

Control of CRS would rely on narrow range oil, Esteem, Applaud, limited use of the neonicotinoid insecticide Admire and the mass release of *Aphytis*. About 1/4 to 1/2 of the acreage would receive an application of narrow range oil, Esteem, Applaud, or Admire, and about 1/4 of the acreage would receive the mass release of *Aphytis*. The use of Esteem, Applaud, and Admire would occasionally cause CCS outbreaks requiring releases of vedalia beetles. Vedalia beetle releases would be needed in early spring, after insecticide residues from the previous year had worn off, wherever CCS were found. Esteem would have little or no effect on CS and so populations of CS would increase following use of Esteem. If a cost effective program for inundate releases of *Metaphycus* parasites could be established, then insecticide control would not be necessary. The neonicotinoid insecticide Admire not only provides moderately effective control of CRS but good control of CS. It is anticipated when additional neonicotinoid insecticides are registered (acetamiprid (Assail) and thiomethoxam (Platinum)) that they will provide control of CS, but will not be effective against CRS and will cause the same problems with CCS that Admire causes. The use of the mass release of A*phytis* for CRS control is limited to orange groves with low populations of sugar-feeding ants (AA and NGA). AA and NGA protect CRS from parasitization by *Aphytis*. However, boric acid (or other toxicants) mixed with a sugar bait solution is effective for controlling NGA and AA. However, the baits are very expensive and labor intensive. Bait containers (25/acre) are needed every fourth tree and must be refilled with liquid every 2-4 weeks depending on the ant densities. If this can be made more cost effective, it has promise for sugar-feeding ant control.

CRM can be a significant pest and requires control actions. Less than 1/10 of the acreage would be treated with narrow range oil, Omite, Nexter, Vendex, or Kelthane for CRM control. Also lepidopteran species can be significant pests and require control actions. About 1/10 to 1/4 of the acreage would be treated with Bt or Success. Both insecticides work best on young larvae and so timing of insecticide treatments would be critical. Control of protein-feeding ants (SFA) would rely on Clinch or Esteem Ant Bait and about 1/10 to 1/4 of the acreage would be treated with either of these products. GWSS would be treated with Admire or Platinum and the CCS outbreaks that could arise would be ameliorated with vedalia releases when the pesticide residues had worn off.

Addendum

Two new insecticides, buprofezin (Applaud) and acetamiprid (Assail), have been registered in oranges since the economic analysis. Applaud will be used for California red scale control and compete with Esteem. It is likely that the use of Applaud will cause outbreaks of cottony cushion scale in a manner similar to, although less severe than, Esteem. Assail will provide control of Citricola scale and glassy-winged sharpshooter and compete with the other neonicotinoid insecticides Provado/Admire. Hopefully the registration of Assail will help reduce the costs of the neonicotinoid insecticides. While Assail is a reduced risk insecticide, it has fairly broad spectrum of activity against a number of beneficial insects and mites and so will have limited use in citrus IPM programs.

Table 1. Insecticide and Miticide Use on Oranges in Southern Coastal and Interior Valleys of Southern California, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
abamectin	2	218	0.8	$10,667
(Agri-mek, Clinch Ant Bait)				
Bacillus thuringiensis	1	13	>0.1	$16
(Various Products)				
carbaryl	10,582	1,750	5.8	$73,652
(Sevin)				
chlorpyrifos	8,979	14,395	48	$169,889
(Lorsban)				
cryolite	192	10	>0.1	$482
(Kryocide, Prokil)				
cyfluthrin	59	699	2.3	$17,240
(Baythroid)				
dimethoate	746	483	1.6	$7,350
(Dimethoate)				
formetanate hydrochloride	18	50	0.2	$803
(Carzol)				
narrow range oil	384,081	11,461	38.3	$211,245
(Petroleum Products)				
malathion	59	538	1.8	$320
(Malathion)				
methidathion	1,012	337	1.1	$28,350
(Supracide)				
methomyl	21	23	>0.1	$460
(Lannate)				
spinosad	87	1,180	3.9	$27,850
(Success)				

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation Pesticide Use Reports). Average insecticide (material) cost per acre planted for the Southern Coastal and Interior Valleys of Southern California is about $18.52.

Table 2. Insecticide and Miticide Use on Oranges in the San Joaquin Valley of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
abamectin (Agri-mek, Clinch Ant Bait)	99	12,140	6.9	$494,640
Bacillus thuringiensis (Various Products)	2,068	25,354	14.4	$63,856
buprofezin (Applaud)	20,051	12,338	7	$257,856
carbaryl (Sevin)	41,363	5,902	3.4	$287,890
chlorpyrifos (Lorsban)	149,736	50,210	28.6	$2,833,008
cryolite (Kryocide, Prokil)	58,900	5,165	2.9	$147,838
cyfluthrin (Baythroid)	6,485	66,136	37.7	$1,880,525
dimethoate (Dimethoate)	21,416	12,588	7.2	$210,948
encapsulated delta endotoxin (MVP II)	1,897	4,201	2.4	$33,704
formetanate hydrochloride (Carzol)	7,437	7,179	4.1	$324,485
narrow range oil (Petroleum Products)	3,982,070	159,852	91	$2,190,139
malathion (Malathion)	63,872	7,468	4.3	$349,377
methidathion (Supracide)	33,467	12,703	7.2	$937,065
methomyl (Lannate)	3,866	4,464	2.5	$85,913
pyridaben (Nexter)	2,646	6,958	4	$493,871
pyriproxyfen (Esteem)	2,234	21,678	12.3	$1,247,030
spinosad (Success)	8,081	77,749	44.3	$2,586,000

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre planted for the San Joaquin Valley is about $82.79.

Table 3. Insecticide and Miticide Use in an OP free Pest Management System with Available Technology on Orange in Southern Coastal and Interior Valleys of Southern California

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
narrow range oil	20 gal	0.25	CRS & black scale	
or				
carbaryl (Sevin XLR Plus or 80S)	15 lb		CRS & CCS	May cause increase in mites
or				
pyriproxifen (Esteem)	16 oz		CRS	May cause increase in CS sprayaed orchards and CCS in neighboring orchards
or				
imidacloprid (Admire)	32 oz		CRS & CS	May cause increase in CCS
or				
buprofezin (Applaud)	2.1 lb		CRS & CS	May cause increase in CS sprayed orchards and CCS in neighboring orchards
Aphytis releases	40,000/yr	0.25	CRS, CS & CCS	
abamectin (Clinch Ant Bait)	1 lb	0.10	SFA	May not prevent damage to young trees
or				
pyriproxyfen (Esteem Ant Bait)	2 lb			May not prevent damage to young trees
spinosad (Success)	6 oz	.25	CT & FK	Not effective against large instars of FK
+ narrow range oil	1 qt			
or				
cyfluthrin (Baythroid 2E)	6 oz		CT	Resistance in some populations
or				
fenpropathrin (Danitol 2.4 EC)	21 1/3 oz			
or				
formetanate hydrochloride (Carzol 92SP)	1 lb		CT	Resistance in some populations
or				
abamectin (Agri-Mek 0.15EC)	10 oz		CT	

+ narrow range oil	1 qt			
cryolite (Kryocide 96WP, Prokil 96)	15 lb		FK	Not effective against large instars
B. thuringiensis var. *kurstaki* (Dipel DF, MVP, Javelin)	2 lb	0.10	Lepidopteran pests	Slow acting
or				
spinosad (Success)	6 oz	.25		May not control large instars
or				
methomyl (Lannate LV)	2 pt			May cause outbreaks of mites
Narrow range oil	20 gal	0.10	CRM	
or				
pyridaben (Nexter)	1/2 lb			
or				
dicofol (Kelthane 4E)	6 pt			
or				
fenbutatin oxide (Vendex)				
or				
propargite (Omite CR or 30W)	10 lb			

Table 4. Insecticide and Miticide Use in an OP free Pest Management System with Available Technology on Oranges in the San Joaquin Valley

Material	**Rate Form/ac**	**# Appl./ Season**	**Pest**	**Notes**
spinosad (Success)	6 oz	1.5	CT & FK	Not effective against large FK instars
+ narrow range oil	1 qt			
or				
cyfluthrin (Baythroid 2E)	6 oz			Resistance in some CT populations
or				
fenpropathrin (Danitol 2.4 EC)	21 1/3 oz			
or				
formetanate hydrochloride (Carzol 92SP)	1 lb			Resistance in some CT populations
or				
abamectin (Agri-Mek 0.15EC)	10 oz		CT	
+ narrow range oil	1 qt			
cryolite (Kryocide 96WP, Prokil 96)	15 lb		FK	Not effective against large instars
narrow range oil	20 gal	0.5	CRS	
or				
pyriproxifen (Esteem)	16 oz		CRS	May cause increase in CS sprayed orchards and CCS in neighboring orchards
or				
buprofezin (Applaud)	2.1 lb		CRS & CS	May cause increase in CS sprayed orchards and CCS in neighboring orchards
or				
carbaryl (Sevin XLR Plus or 80S)	15 lb		CRS, CCS, CS	May cause increase in mites
or				
imidacloprid (Admire)	32 oz		CRS, CS	May cause increase in CCS
Aphytis releases	100,000/yr	0.25	CRS	
imidacloprid16 oz (Provado)		CS		May cause increase in CCS

or				
acetamiprid (Assail)	5.7 oz		CS	May cause increase in CCS
abamectin (Clinch Ant Bait)	1 lb	0.25	SFA	May not prevent damage to young trees
or				
pyriproxyfen (Esteem Ant Bait)	2 lb			May not prevent damage to young trees
B. thuringiensis var. *kurstaki* (Dipel DF, MVP, Javelin)	2 lb	0.25	Lepidopteran pests	Slow acting
or				
methomyl (Lannate LV)	2 pt			May cause increase in mites
or				
spinosad (Success)	6 oz			May not control large larvae
narrow range oil	20 gal	0.25	CRM	
or				
pyridaben (Nexter)	1/2 lb			
or				
dicofol (Kelthane 4E)	6 pt			
or				
fenbutatin oxide (Vendex)				
or				
propargite (Omite CR or 30W)	10 lb			
imidacloprid (Admire)	32 oz	0.10	GWSS	May cause increase in CCS
or				
acetamiprid (Assail)	2.9 oz		CWSS	May cause increase in CCS

Table 5. Insecticide and Miticide Use in an OP free Pest Management System with Emerging Technology on Oranges in the San Joaquin Valley and Southern Coastal and Interior Valleys of Southern California

Material	Rate Form/ac	# Appl./ Season	Pest	Notes
spinosad	6 oz	1.5	CT & FK	Not effective against
(Success)				large FK instars
+ narrow range oil	1 qt			
or				
cyfluthrin	6 oz			Resistance in some
(Baythroid 2E)				CT populations
or				
fenpropathrin	21 1/3 oz			
(Danitol 2.4 EC)				
or				
abamectin	10 oz	CT		
(Agri-Mek 0.15EC)				
+ narrow range oil	1 qt			
cryolite	15 lb	FK		Not effective against
(Kryocide 96WP, Prokil 96)				large instars
narrow range oil	20 gal	0.5	CRS	
or				
pyriproxifen	16 oz		CRS	May cause increase in CS
(Esteem)				sprayed orchards and CCS in neighboring orchards
or				
buprofezin	2.1 lb		CRS & CS	May cause increase in CS
(Applaud)				sprayed orchards and CCS in neighboring orchards
or				
carbaryl	15 lb		CRS, CCS, CS	May cause increase in
(Sevin XLR Plus or 80S)				mites
or				
imidacloprid				
(Admire)	32 oz		CRS, CS	May cause increase in
or				CCS
Aphytis releases	40,000/yr	0.25		CRS
Vedalia beetle releases	100/orchard		CCS	Not effective if IGRs and neonicotinoids recently used.
Imidacloprid	16 oz		CS	May cause increase in
(Provado)				CCS, CRS
or				
acetamiprid				
(Assail 70WP)	1/4 lb		CS	May cause increase in CCS
or				
thiomethoxam				
(Platinum)			CS	Not Registered

Boracic acid (Boric acid sugar bait system)	0.1-0.5		NGA & AA	Not Registered
abamectin (Clinch Ant Bait)	1 lb	0.1-0.25	SFA	May not prevent damage to young trees
or				
pyriproxyfen (Esteem Ant Bait)	1.5-2 lb			May not prevent damage to young trees
B. thuringiensis var. *kurstaki* (Dipel DF, MVP, Javelin)	2 lb	0.1-0.25	Lepidopteran pests	slow acting
or				
spinosad (Success)	6 oz	.25		May not control large larvae
narrow range oil	20 gal	0.1-0.25	CRM	
or				
pyridaben (Nexter)	1/2 lb			
or				
dicofol (Kelthane 4E)	6 pt			
or				
propargite (Omite CR and 30W)	10 lb			
imidacloprid (Admire)	32 oz	0.1	GWSS	May cause increase in CCS
or				
acetamiprid (Assail 70WP)	2.9 oz		GWSS	May cause increase in CCS
or				
thiomethoxam (Platinum)				Not Registered. May cause increase in CCS

PEACHES AND NECTARINES

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California produces about 70% of the peaches and over 95% of the nectarines in the United States on over 100,000 acres. Peaches and nectarines are produced in the southern San Joaquin Valley and the northern San Joaquin and Sacramento valleys. The southern San Joaquin Valley contains about 2/3 of the statewide acreage and produces virtually all the fresh market nectarines and freestone peaches in the state. The northern San Joaquin and Sacramento valleys contain about 1/3 of the statewide acreage and produce most of the canning peaches in the state. There is a small amount of production (less than 1.5%) in the coast, desert and mountain areas and this production is not considered in this report.

There are numerous arthropod pests of peaches and nectarines. The arthropod pest complex is similar between the two crops and major production regions. The major arthropod pests include San Jose scale, Oriental fruitmoth, peach twig borer, fruittree leafroller, omnivorous leafroller, western flower thrips, the web-spinning spider mites of the genus *Tetranychus* and European red mite. These species require control measures nearly every year. Species that cause damage less frequently include the true bugs, peach silver mite, katydids, flatheaded borer, prune limb borer, American plum borer and shothole borer. While these species may occur sporadically, they can cause significant economic damage.

A complicating factor in the construction of a pest management program is the extended harvest period of peaches and nectarines. Unlike many commodities, harvest is spread across many peach and nectarine varieties that ripen from late April through early October. Some varieties are more susceptible to damage because they may ripen later in the season and are exposed to more generations of a pest. Likewise, a variety may or may not be susceptible to certain pests depending on whether its period of susceptibility is synchronized with the pest's phenology. In general, late maturing varieties require more intensive pest control than early maturing varieties.

San Jose Scale (SJS), Quadraspidiotus perniciosus

The San Jose scale is a major pest on both peaches and nectarines. The adults feed on limbs, twigs and fruit by inserting their mouthparts into the tissue of the tree or fruit and removing plant fluids. When feeding occurs on the wood, it removes necessary nutrients from the tree thereby reducing the tree's vigor. When feeding occurs on the fruit, it causes a characteristic red spot of discoloration around the insect's body that causes the fruit to be culled. High populations may seriously weaken or kill fruiting branches and can cause permanent damage to the tree. SJS is controlled by a dormant application of horticultural oil combined with an organophosphate (OP) insecticide. The dormant application usually provides adequate SJS control for peaches but may not provide adequate SJS control for nectarines where the tolerances for fruit damage is very low. An in-season application of an OP insecticide timed to the susceptible crawler stage of the scale may be needed in nectarines. Two parasites (*Encarsia perniciosi* and *Aphytis sp.)* and two predacious beetles (*Chilocorus orbus* and *Cybocephalus californicus*) will suppress the SJS population. However, in-season applications of an OP insecticide will largely eliminate these beneficial insects.

Peach Twig Borer (PTB), *Anarsia lineatella*

The peach twig borer is a major pest of both peaches and nectarines. PTB larvae damage peaches and nectarines by feeding within growing shoot tips. This feeding causes the shoots to die back and axial twigs to grow. This damage is usually insignificant on mature trees, but on newly planted trees it reduces the choice of branches available for developing a productive tree structure. The most significant damage occurs when larvae enter the fruit and cause the fruit to be unmarketable. PTB is controlled by a dormant application of horticultural oil combined with an OP insecticide. A dormant application controls the overwintering PTB larvae and is usually sufficient for early-harvesting varieties. Mid-harvesting and late-harvesting varieties often need an additional in-season application of an OP insecticide. Natural enemies, such as the chalcid wasps (*Paralitomastix varicornis* and *Hyperteles lividus*) and the native gray ant (*Formica spp.*), can destroy a significant number of larvae, however these beneficial insects seldom reduce PTB populations below economically damaging levels.

Oriental Fruit Moth (OFM), *Grapholita molesta*

The Oriental fruit moth larvae feed within the growing shoot tips and cause shoot die back, particularly early in the season. As with PTB, this feeding causes shoots to die back and axial twigs to grow. This damage is usually insignificant on mature trees but on newly planted trees it reduces the choice of branches available for developing a productive tree structure. The most significant damage occurs when larvae enter the fruit and cause the fruit to be unmarketable. However, OFM produces more generations per year than PTB and can cause more significant damage to fruit on late season maturing varieties than PTB. OFM is not controlled by dormant applications of horticultural oil combined with an OP insecticide. Control of OFM relies on multiple in-season applications of OP insecticides timed to early larval development in each generation. In addition to in-season OP insecticides, mating disruption has also successfully controlled OFM. Mating disruption has provided control for early maturing varieties without supplemental in-season OP insecticide applications. However, additional OP applications are usually required for late-maturing varieties.

Omnivorous Leafroller (OLR), *Platynota stultana*

The omnivorous leafroller is a pest in the San Joaquin Valley. It also occurs in the Sacramento Valley, but rarely causes economic damage. The larvae feed on both the foliage and fruit. Foliage damage is very minor while fruit that is fed upon will be culled at harvest. Treatments for PTB and OFM will usually control OLR. Control has relied on *Bacillus thuringiensis* (Dipel and others), diazinon (Diazinon), chlorpyrifos (Lorsban) and phosmet (Imidan). However, as growers have relied on mating disruption of OFM control, OLR has become a more persistent problem in the southern San Joaquin Valley.

Fruittree Leafroller (FTLR), *Archips argyrospila*

The fruittree leafroller is a pest of all stone and pome fruit. There is only one generation per year and FTLR overwinter in egg masses on branches or tree trunks. The larvae emerge in early spring around bloom time. The larvae feed on both the foliage and fruit. Foliage damage is very minor while fruit that is fed upon will be culled at harvest. FTLR is usually controlled by the dormant spray of an OP insecticide combined with horticultural oil that is applied for PTB and SJS. The bloom spray aimed at thrips in nectarines adds additional control. Occasionally additional sprays are needed to control larval feeding on fruit.

True bugs (TB)

Stink Bugs (SB)

Euschistus conspersus,
Thyanta pallidovirens
Acrosternum hilare,
Chlorochroa uhleri

Lygus Bugs (LB)

Lygus hesperus
Lygus elisus

Plant Bug (PB), *Calocoris norvegicus*

True bugs are considered a major pest to peaches and nectarines can cause serious damage. These pests disperse into peach and nectarine orchards from adjacent host crops and uncultivated areas. TB can also develop on weeds on the orchard floor. TB damage is caused when the bugs insert their piercing-sucking mouthparts into the fruit to feed and inject saliva that causes the fruit tissue to break down.

Several species of SB can damage peaches and nectarines. When SB feed on small fruit the damaged tissue fails to grow so that the fruit becomes irregularly shaped. When SB feed on more mature fruit, the fruit has sunken and bruised spots. These spots are discolored with callous tissue. In either case the fruit is culled out. One bug may damage several fruit so that a few insects can cause a significant amount of damage. From year to year, damage levels are unpredictable because of the cyclic nature of the population and differences in suitability and abundance of overwintering hosts.

LB and PB are similar in appearance and their damage is somewhat similar to SB damage. LB and PB can be numerous and can be severe. Damaged fruit are misshapen or can have numerous small corky spots. Damage can also occur when LB and PB feed on new developing shoot tips. This feeding causes the shoots to die back and axial twigs to grow. Since LB and PB populations vary annually, damage varies considerably from year to year. Populations are dependent on the abundance and makeup of winter annual vegetation in and around orchards. Large populations can build up on legumes and crucifers, which are LB's and PB's preferred hosts. If a significant portion of the vegetation around the orchards are host plants and if prolonged spring rains keep vegetation green and flowering late in the spring, then high LB and PB will be expected in the orchards. In addition, mowing the cover crop of weeds in the orchard when LB and PB are in the adult stage will cause the adults to disperse into the tree canopy and may greatly increase damage.

Since true bugs are migratory and damage can occur rapidly, insecticides must have contact activity and be fast acting. The timing of control is difficult because true bugs are often not observed until damage already has occurred. Control of true bugs has relied on OP, carbamates and the cyclodiene insecticides. The primarily insecticides used to control true bugs are endosulfan (Thiodan), formetanate hydrochloride (Carzol) or methomyl (Lannate). However, the pre-harvest interval for Carzol has recently been lengthened which will limit Carzol use.

Western Flower Thrips (WFT), *Frankliniella occidentalis*

The western flower thrips is an important pest of smooth-skinned stone fruits such as nectarines and plums. Peaches are occasionally damaged by WFT but only by excessively high populations. Thrips are attracted to the flower buds early in the season and will feed on the new fruit under the dried calyx. The primary damage is caused at bloom or petal-fall when the thrips abrade the fruit's skin with their rasping-sucking mouth parts. The damaged skin does not grow properly resulting in large scars and misshapen fruit at maturity. Thrips also can feed on mature fruit that results in "bleached-out" areas. This is most noticeable on the red nectarine varieties, which are the most profitable. Early season thrips damage is usually controlled with Carzol applied at petal-fall while late season damage is controlled with Lannate applied two or three weeks prior to harvest.

Spider Mites:

Twospotted Spider Mite (TSSM), *Tetranychus urticae*
Pacific Spider Mite (PSM), *Tetranychus pacificus*
European Red Mite (ERM), *Panyonychus ulmi*
Brown Mite (BM), *Byrobia rubioculus*

Twospotted spider mites and Pacific spider mites can cause significant damage to peaches and nectarines. The spider mites feed on leaves and reduce the photosynthetic potential of the trees. Heavy mite populations affect fruit sizing and soluble solids and can lead to defoliation. TSSM and PSM are not affected by dormant applications and must be controlled with in-season miticides. While OP insecticides have little direct effect on TSSM and PSM, some OP insecticides, e.g. azinphos-methyl (Azinphos-M), will eliminate most spider mite predators. Without predators, spider mite populations can rapidly increase to damaging levels. The short-term alternatives to OP insecticides are pyrethroid insecticides, e.g. esfenvalerate (Asana) or permethrin (Pounce or Ambush). However, the currently registered pyrethroid insecticides are highly detrimental to spider mite predators. Spider mites can be controlled in both peaches and nectarines with fenbutatin oxide (Vendex) and clofentezine (Apollo). Propargate (Omite) is also used in nectarine orchards for control.

ERM and BM are usually not major pests of peaches and nectarines. However, damaging populations can occur when OP or pyrethroid insecticides have eliminated beneficial insects and mites. ERM and BM overwinter as eggs on the tree and are controlled with dormant horticultural oil applications. OP insecticides that are combined with the horticultural oil have very little effect on ERM or BM mortality. Occasionally ERM or BM populations increase to a damaging level and an application of a miticide, e.g. Vendex or Apollo, is required for their control. Omite is also used in nectarine orchards for control.

Katydids

Angularwinged Katydid, *Microcentrum retinerve*
Forktailed Bush Katydid, *Scudderia furcata*

Katydids have historically been sporadic pests of peaches and nectarines and only develop damaging populations in orchards that have not applied an OP insecticide. However, katydids have become serious pests over the last few years in the southern San Joaquin Valley as OP insecticide use has been reduced. Katydids are very sensitive to OP insecticides, particularly Lorsban. Most damage occurs early in the season when katydids feed on the developing fruit. Both nymphs and adult katydids feed on the fruit surface. If the fruit does not abort from early damage, then the feeding injury will heal and the scar is retained until harvest. Damage on mature fruit results in a shallow whitish pit in the fruit surface. Insecticide applications for other orchard pests, such as OFM, usually control katydids. However, occasional heavy populations may require specific treatments with a low rate of an OP insecticide or spinosad (Success).

Current Pest Management Program

Southern San Joaquin Valley

The southern San Joaquin Valley, which contains Fresno, Kings, Tulare, Kern and Madera, counties, produces over 90% of fresh market peaches and 95% of fresh-market nectarines. Early season harvest of fresh market peaches begins in April and continues into October. The late season harvest in October requires more intense use of insecticide/miticides to produce blemish free fresh market fruit than fruit harvested in April.

The majority of peach and nectarine orchards received a dormant application of an OP insecticide, e.g. Diazinon, Lorsban, or methidathion (Supracide), combined with horticultural oil for control of PTB, SJS, FTLR, BM and ERM in 1999 (Table 1). Occasionally, carbaryl (Sevin) was used in place of the OP insecticides. In recent years the use of pyrethroid insecticides, i.e. permethrin (Pounce/Ambush) and esfenvalerate (Asana), has increased and replaced some of the OP insecticides. However, the pyrethroid insecticides are known to exacerbate spider mite problems. Thus, pyrethroid insecticides, particularly permethrin, are not used to the extent in the southern San Joaquin Valley as in the northern San Joaquin and Sacramento valleys. Pyrethroid insecticides also are not effective against SJS.

In addition to dormant applications, control of PTB has relied on bloom applications of Bt. Bt was used on about 50% of the in 1999. Control of thrips injury on nectarines requires a bloom or petal fall application. Typically treatments are made using a carbamate insecticide either Carzol or Lannate. Success has been shown to be an effective alternative to Carzol for thrips control and has replaced Carzol on a significant amount of acreage. In addition, Carzol can no longer be applied after bloom. Success also controls PTB when applied at bloom or petal fall. In addition to the control of thrips, Carzol and Lannate werw also applied for control of true bugs.

Control of OFM has relied on a second-generation application of OP insecticide, e.g. methyl parathion (Penncap-M), Diazinon, Lorsban or Imidan, in mid- to late May. However, Penncap-M is no longer registered on peaches or nectarines. Occasionally, heavy OFM populations would be treated in the first generation. Early harvested varieties may only require one treatment for adequate control, but mid- to late season varieties may need additional treatments at each generation. Pheromone mating disruption came into use for OFM management about ten years ago and was used on over 25% of the acreage. The use of mating disruption has declined because pests that were controlled by insecticide applications for OFM, e.g. omnivorous leafroller and obliquebanded leafroller, were building up to damaging levels. Growers have combined pheromone-mating disruption of OFM with one OP insecticide application with good results for both OFM and OBLR control.

Spider mites can be a significant pest in the southern San Joaquin Valley. About 50% of the acreage received a miticide [clofentezine (Apollo), dicofol (Kelthane), fenbutatin-oxide (Vendex) or propargite (Omite)] for spider mite control. About three to five applications of insecticides/miticides per acre were applied for fresh market peach or nectarine production in 1999. The average insecticide (material) cost per acre for the southern San Joaquin Valley is about $109 for both peaches and nectarines.

Northern San Joaquin and Sacramento Valley

Northern San Joaquin and Sacramento valleys, which contain Merced, Stanislaus, San Joaquin, Solano, Yolo, Sacramento, Placer, Sutter, Yuba, Butte and Tehama counties, produce very little fresh market peaches or nectarines. However, the northern San Joaquin and Sacramento valleys produce over 90% of the Clingstone (processed) peaches in the state. Processing peaches are harvested from July to mid-September. Grade standards for processing peaches may be more difficult to attain because damaged fruit is not culled out across a packing line as is fresh fruit. An entire load of processing fruit may be refused at the processing plant because of excess insect damage. Therefore growers may be less likely to adopt pest control practices perceived as "risky" for processing peaches than they would for fresh market fruit.

The majority of peach orchards received a dormant application of pyrethroid insecticides combined with horticultural oil for control of PTB, SJS, FTLR, BM and ERM (Table 2). In recent years the pyrethroid insecticides have largely replaced the dormant OP insecticides. Some dormant OP insecticides are still applied in situations where SJS are a problem. The change from OP to pyrethroid insecticides is the result of the lower price of the pyrethroids and concern by growers of the OP insecticides that have been found in the Sacramento and Feather rivers. In 1999, more than one application of a pyrethroid insecticide was applied per acre while only about three quarters of an application of OP insecticides was applied per acre. In addition, the spider mite problems associated with pyrethroid insecticides in the southern San Joaquin Valley are less of a concern in the northern San Joaquin and Sacramento valleys. Higher humidity and lower temperatures in the northern San Joaquin and Sacramento valleys as compared to the southern San Joaquin Valley help suppress spider mite populations. In addition, the western predator mite, *Galandromus (Typhlodromus) occidentalis*, has developed a measure of resistance to the pyrethroid insecticides, particularly Asana. Since thrips injury is not a significant problem on processing peaches and true bugs are sporadic pests in isolated peach orchards, very little Carzol or Lannate was applied to processing peaches in the northern San Joaquin and Sacramento valleys.

Control of OFM has relied on a second-generation application with pyrethroid or OP insecticide in mid- to late May. Occasionally, heavy OFM populations would be treated in the first generation. Pheromone mating disruption came into use for OFM management about ten years ago and was used on 25% of the acreage. The use of mating disruption has declined. However, a significant acreage is treated with OFM pheromone mating disruption combined with one pyrethroid or OP insecticide application.

Spider mites can be a significant pest in northern San Joaquin and Sacramento valleys following the use of pyrethroid insecticides. About 50% of the acreage received a miticide (Apollo, Kelthane and Vendex) for control of spider mites. The total acreage treated with a miticide was similar between the northern San Joaquin and Sacramento valleys and southern San Joaquin Valley. However, there was a shift in the miticides. In the northern San Joaquin and Sacramento valleys, Vendex was the predominate miticide and less then 1% of the acreage was treated with Omite while in the southern San Joaquin Valley Omite and Vendex were the predominate miticides. Since Omite is only registered on nectarines, the lack of Omite use in northern San Joaquin and Sacramento valleys reflects the lack of nectarines grown in this region. About three to four applications of insecticides/miticides per acre were applied for processing peach production in 1999. The average insecticide (material) cost per acre for the northern San Joaquin and Sacramento valleys is about $62 for both peaches and nectarines.

OP Free – Pest Management Program with Available Technology

The OP-free programs below were constructed with currently registered insecticides for immediate implementation and without regard to resistance management consequences. The pest management programs outlined below would prevent significant damage in excess of current levels. A pest management program in peaches and nectarines, regardless of the pest pressure or location in the state, would rely on a dormant/delayed dormant application of a pyrethroid insecticide or pyriproxyfen (Esteem) combined with horticultural oil for control of PTB, SJS, FTLR, BM and ERM and mating disruption for control of OFM. A pyrethroid insecticide would be used in the dormant/delayed dormant application if PTB was the primary pest while Esteem would be used if SJS was the primary pest. It is anticipated that there would be no significant yield decrease over current levels with the elimination of the OP insecticides.

In early maturing peach and nectarine varieties and/or late maturing varieties with low pest pressure in the southern San Joaquin Valley, pest management program would require an application of Success for WFT, katydids and additional OFM control and about half of the acreage would require an application of Bt at bloom for additional PTB control (Table 3). Since pyrethroid insecticides would only be applied during the dormant period, spider mites would not be a significant in-season problem and about half of the acreage would receive an application of Apollo, Vendex or Omite for spider mite control. Omite is not registered on peaches and would only be applied to nectarines.

In late maturing peach and nectarine varieties and/or early maturing varieties with high pest pressure in the southern San Joaquin Valley, the pest management programs without OP insecticides would require significantly more applications to maintain control. In addition to dormant applications for PTB, SJS, FTLR, BM and ERM control and mating disruption for control of OFM, an application of Success would be required for WFT, katydids and additional OFM control and an application of Bt at bloom would be required for additional PTB control (Table 4). About half of the acreage would receive an application of Carzol or Lannate for additional WFT and TB control, particularly in nectarines, and about half of the acreage would receive an application of a pyrethroid insecticide for additional OFM and TB control. Since in-season use of pyrethroid insecticides would eliminate most predators of spider mites and since about half the acreage would receive an in-season pyrethroid insecticide for additional control of OFM and TB, TSSM and PSM would be a significant problem. An application of Apollo, Vendex or Omite would be required to control TSSM and PSM. This pest management system would be very unstable and would lead to the rapid development of TSSM and PSM resistance to all available miticides and can be expected to develop uncontrollable spider mite populations within a few years of implementation. In addition, the pyrethroid insecticides would largely deplete the predators and parasites of SJS. Pyrethroid insecticides are not effective for scale control.

In processing peaches in the northern San Joaquin and Sacramento valleys, dormant applications would be applied for control of PTB, SJS, FTLR, BM and ERM and mating disruption would be applied for control of OFM (Table 5). In addition, an application of Success would be required for additional PTB, OBLR and OFM control. Also about half of the acreage would require an application of Bt at bloom for additional PTB control and about half the acreage would require an in-season pyrethroid insecticide for additional control of OFM and TB. Because of the in-season and dormant pyrethroid applications, spider mites may develop significant problems in about half of the acreage. However, higher humidity and lower temperatures in the northern San Joaquin and Sacramento valleys as compared to the southern San Joaquin Valley help suppress spider mite populations. Again, the western predator mite, *Galandromus (Typhlodromus) occidentalis*, has developed a measure of resistance to the pyrethroid insecticides, particularly Asana, in the northern San Joaquin and Sacramento valleys. Thus spider mites would require an application of Apollo or Vendex on about half of the acreage to maintain control but would not develop uncontrollable populations. Omite can be applied to nectarines as well. Since few nectarines are grown in the northern San Joaquin and Sacramento valleys, very little or no Omite would be applied in the northern San Joaquin and Sacramento valleys.

OP Free – Pest Management Program with Emerging Technology

The IPM programs below were constructed with currently registered insecticides and/or insecticides that are anticipated to be registered within four to five years. The intent of the pest management program with emerging technology is to produce a stable long-term program that would allow for much greater impact of beneficial insects and mites on the pest populations. The pest management program would maintain low pest densities over time and prevent large pest density oscillations.

Pest management programs would rely on mating disruption for control of OFM and a dormant application of horticultural oil combined with Success or Esteem depending on the pest species and population density. In early maturing peach and nectarine varieties and/or late maturing varieties with low pest pressure in the southern San Joaquin Valley, the pest management program would require a dormant application of horticultural oil combined with Success or Esteem (Table 6). Success would be used when PTB is the dominate pest while Esteem would be used when SJS in the dominate pest. Success would also be required for WFT and katydid control on about a quarter of the acreage. Additional OFM control would rely on acetamiprid (Assail) or Calypso and additional PTB control would rely on Bt or methoxfenozide (Intrepid) applied at bloom to about a quarter of the acreage. Since pyrethroid insecticides would not be applied during the dormant period or in-season, TSSM or PSM would not cause significant damage. About a quarter of the acreage would receive an application of Apollo, Vendex or abamectin (Agri-Mek) plus horticultural oil to maintain spider mite populations. It is anticipated that Omite will lose its registration on nectarines within the next five years.

In late maturing peach and nectarine varieties and/or early maturing varieties with high pest pressure in the southern San Joaquin Valley, the pest management program would require a dormant application of horticultural oil combined with a pyrethroid insecticide or Esteem (Table 7). The pyrethroid would be used when PTB is the dominate pest while Esteem would be used when SJS in the dominate pest. Success would also be required for WFT and katydid control on about half of the acreage. Additional OFM control would rely on Assail or Calypso and additional PTB control would rely on Bt or Intrepid applied at bloom to about half of the acreage. In addition, about a quarter of the acreage would require an application of imidacloprid (Provado) for TB control. Since pyrethroid insecticides would only be applied during the dormant period and not to all acres, spider mites would not cause significant damage and about half of the acreage would receive an application of Apollo, Vendex or Agri-Mek plus horticultural oil to maintain spider mite populations.

In processing peaches in the northern San Joaquin and Sacramento valleys, the pest management program would require a dormant application of horticultural oil combined with a pyrethroid insecticide or Esteem (Table 8). The pyrethroid insecticide would be used when PTB is the dominate pest while Esteem would be used when SJS in the dominate pest. Success would also be required for OBLR and PTB control on about a quarter of the acreage. Additional OFM control would rely on Assail or Calypso and about half the acreage would be treated while additional PTB control would rely on Bt or Intrepid applied at bloom to about a quarter of the acreage. In addition, about a quarter of the acreage would require an application of Provado for TB control. Since pyrethroid insecticides would only be applied during the dormant period and not to all acres, spider mite damage would not be a significant problem and about half of the acreage would receive an application of Apollo, Vendex or Agri-Mek plus horticultural oil to maintain spider mite populations.

Addendum

A number of miticides have been registered in peach/nectarine since the economic analysis. These include hexythiazox (Savey), pyrdiaben (Pyramite) and bifenazate (Acramite). These new miticides will be added to the existing arsenal of miticides, e.g., propargite (Omite), clofentezine (Apollo), dicofol (Kelthane) and fenbutatin-oxide (Vendex). Savey, Pryamite and Acramite will add new modes of action and increase the number of available miticides. This should help stabilize or slow the development of miticide resistance and hopefully reduce miticide costs. However, these new products will not have a major impact on peach/nectarine IPM.

Table 1. Insecticide and Miticide Use on Nectarines and Peaches in the Southern San Joaquin Valley in CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
azinphos-methyl (Guthion)	2,231	1,425	1.9	$46,368
Bacillus thuringiensis (Various Products)	3,952	40,415	53	$122,035
carbaryl (Sevin)	18,250	5,179	6.8	$127,017
chlorpyrifos (Lorsban)	45,459	24,474	32.1	$860,076
clofentezine (Apollo)	1,899	12,967	17	$725,502
diazinon (Diazion)	36,330	19,968	26.2	$335,693
dicofol (Kelthane)	7,079	5,223	6.9	$199,048
encap delta endotoxin (MVP II)	1,830	2,936	3.9	$32,512
esfenvalerate (Asana)	1,782	43,274	56.8	$324,065
fenamiphos (Nemcur)	1,321	573	0.8	$15,426
fenbutatin-oxide (Vendex)	8,575	11,843	15.5	$474,514
formetanate hydrochloride (Carzol)	38,153	37,176	48.8	$1,664,627
horticultural oil (Petroleum products)	2,257,348	70,334	92.3	$1,241,541
methidathion (Supracide)	12,450	6,882	9	$348,614
methomyl (Lannate)	9,851	12,463	16.4	$218,900
methyl parathion (Penncap-M)	23,540	32,540	42.7	$366,761
permethrin (Ambush,Pounce)	28	224	0.3	$1,900
phosmet (Imidan)	81,590	32,188	42.3	$845,277
propargite (Omite)	19,794	10,419	13.7	$384,002

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the Southern San Joaquin Valley is about $109.38.

Table 2. Insecticide and Miticide Use on Nectarines and Peaches in the Northern San Joaquin and Sacramento Valleys in CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
azinphos-methyl (Guthion)	44	34	0.1	$925
Bacillus thuringiensis (Various Products)	490	6,160	15.9	$15,123
carbaryl (Sevin)	9,274	2,361	6.1	$64,545
chlorpyrifos (Lorsban)	1,055	555	1.4	$19,957
clofentezine (Apollo)	364	3,591	9.3	$139,147
diazinon (Diazion)	9,761	6,280	16.2	$90,195
dicofol (Kelthane)	852	662	1.7	$23,971
encap delta endotoxin (MVP II)	12	17	<0.5	$218
esfenvalerate (Asana)	927	20,343	52.4	$168,574
fenamiphos (Nemcur)	3,711	1,286	3.3	$43,341
fenbutatin-oxide (Vendex)	8,992	15,025	38.7	$497,596
formetanate hydrochloride (Carzol)	1,075	1,527	3.9	$46,903
horticultural oil (Petroleum products)	576,663	31,818	82	$317,165
methidathion (Supracide)	6,710	5,340	13.8	$187,870
methomyl (Lannate)	539	466	1.2	$11,980
methyl parathion (Penncap-M)	12,076	16,685	43	$188,145
permethrin (Ambush,Pounce)	6,621	28,114	72.5	$446,891
phosmet (Imidan)	12,030	4,686	12.1	$124,636
propargite (Omite)	168	227	0.6	$3,269

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre treated for the Northern San Joaquin and Sacramento Valleys is about $61.62.

Table 3. Insecticide and Miticide Use in an OP-free IPM System with Available Technology on Early Maturing Peaches and Nectarines Varieties and/or Late Maturing Varieties with Low Pest Pressure in the Southern San Joaquin Valley

Material	**Rate Form./ac**	**# Appl./ Season.**	**Pest**	**Notes**
horticultural oil	4 gal	3/4	PTB, FTLR	Dormant application
+			ERM, BM	would be applied to
esfenvalerate	3/4 pt			all orchards
(Asana XL)				
or				
permethrin	1/2 pt			
(Pounce 3.2 EC)				
horticultural oil	4 gal	1/4	SJS, FTLR	Dormant application
+			ERM, BM	would be applied to
pyriproxyfen	1 pt			all orchards
(Esteem 0.86EC)				
OFM pheromone	125 disp.	1	OFM	
(Isomate-M 100)				
(CheckMate OFM)				
spinosad	1/2 pt	1	PTB, OFM	WFT control is only
(Success)			WFT, FTLR,	required on nectarines
			OBLR,	
			Katydids	
Bacillus thuringiensis	1 lb	1/2	PTB, OBLR	
(Dipel 2X, others)			FTLR	
clofentezine	3/8 pt	1/2	TSSM, PSM	
(Apollo 4SC)				
or				
propargite	6 lb			Nectarines only
(Omite 30W)				
or				
fenbutatin-oxide	1 lb			
(Vendex 50WP)				

Table 4. Insecticide and Miticide Use in an OP-free IPM System with Available Technology on Late Maturing Peaches and Nectarines Varieties and/or Early Maturing Varieties with High Pest Pressure in the Southern San Joaquin Valley

Material	**Rate Form./ac**	**# Appl./ Season.**	**Pest**	**Notes**
horticultural oil	4 gal	3/4	PTB, FTLR	Dormant application
+			ERM, BM	would be applied to
esfenvalerate	3/4 pt			all orchards
(Asana XL)				
or				
permethrin	1/2 pt			
(Pounce 3.2 EC)				
horticultural oil	4 gal	1/4	SJS, ERM	Dormant application
+			BM	would be applied to
pyriproxyfen	1 pt			all orchards
(Esteem 0.86EC)				
OFM pheromone	125 disp.	1	OFM	
(Isomate-M 100)				
(CheckMate OFM)				
spinosad	1/2 pt	1	PTB, OFM	WFT control is only
(Success)			WFT, FTLR	required on nectarines
			OBLR, Katydids	
esfenvalerate	3/4 pt	1/2	OFM, PTB,	In-season applications
(Asana XL)			TB	of pyrethroids may
or				result in increased
permethrin	1/2 pt			spider mite
(Pounce 3.2EC)				populations
methomyl	1 lb	1/2	WFT, TB	
(Lannate SP)				
Bacillus thuringiensis	1 lb	1	PTB, OBLR	
(Dipel 2X, others)	FTLR			
clofentezine	3/8 pt	1	TSSM, PSM	
(Apollo 4SC)				
or				
propargite	6 lb			Nectarines only
(Omite 30W)				
or				
fenbutatin-oxide	1 lb			
(Vendex 50WP				

Table 5. Insecticide and Miticide Use in an OP-free IPM System with Available Technology on Peaches in the Northern San Joaquin and Sacramento Valleys

Material	**Rate Form./ac**	**# Appl./ Season.**	**Pest**	**Notes**
horticultural oil + esfenvalerate (Asana XL) **or** permethrin (Pounce 3.2 EC)	4 gal 3/4 pt 1/2 pt	3/4	PTB, FTLR ERM, BM	Dormant application would be applied to all orchards
horticultural oil + pyriproxyfen (Esteem 0.86EC)	4 gal 1 pt	1/4	SJS, ERM BM	Dormant application would be applied to all orchards
OFM pheromone (Isomate-M 100) (CheckMate OFM)	125 disp.	1	OFM	
spinosad (Success)	1/2 pt	1	PTB, OBLR, FTLR, OFM	
esfenvalerate (Asana XL) **or** permethrin (Pounce 3.2EC)	3/4 pt 1/2 pt	1/2	OFM, PTB, TB	In-season applications of a pyrethroid may result in increased spider mite populations
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1/2	PTB FTLR	
clofentezine (Apollo 4SC) **or** fenbutatin-oxide (Vendex 50WP)	3/8 pt 1 lb	1/2	TSSM, PSM	

Table 6. Insecticide and Miticide Use in an OP-free IPM System with Emerging Technology on Early Maturing Peaches and Nectarines Varieties and/or Late Maturing Varieties with LowPest Pressure in the Southern San Joaquin Valley

Material	**Rate Form./ac**	**# Appl./ Season.**	**Pest**	**Notes**
horticultural oil + spinosad (Success)	4 gal 1/2 pt	3/4	PTB, SJS, ERM, BM, FTLR	Dormant application would be applied to all orchards
horticultural oil + pyriproxyfen (Esteem 0.86EC)	4 gal 1 pt	1/4	SJS, PTB ERM, BM, FTLR	Dormant application would be applied to all orchards
OFM pheromone (Isomate-M 100) (CheckMate OFM)	125 disp.	1	OFM	
spinosad (Success)	1/2 pt	1/4	PTB, OFM, WFT, FTLR OBLR, Katydids	WFT control is only required on nectarines
acetamirpid (Assail 70WP) **or** thiocloprid (Calpso 4SC)	0.2 lb 1/4 pt	1/4	OFM	Not registered Not registered
methoxyfenozide (Intrepid 2F) **or** *Bacillus thuringiensis* (Dipel 2X, others)	1 pt 1 lb	1/4	PTB, OBLR FTLR	Not registered
clofentezine (Apollo 4SC) **or** fenbutatin-oxide (Vendex 50WP) **or** abamectin (Agri-Mek 0.15EC) + Horticultural oil at 0.25% by volume	3/8 pt 1 lb 1 pt	1/4	TSSM, PSM	

Table 7. Insecticide and Miticide Use in an OP-free IPM System with Emerging Technology on Late Maturing Peaches and Nectarines Varieties and/or Early Maturing Varieties with HighPest Pressure in the Southern San Joaquin Valley

Material	**Rate Form./ac**	**# Appl./ Season.**	**Pest**	**Notes**
horticultural oil	4 gal	3/4	PTB, SJS,	Dormant application
+			ERM, BM,	would be applied to
esfenvalerate	3/4 pt	3/4	FTLR	all orchards
(Asana XL)				
or				
permethrin	1/2 pt			
(Pounce 3.2 EC)				
horticultural oil	4 gal	1/4	SJS, PTB	Dormant application
+			ERM, BM,	would be applied to
pyriproxyfen	1 pt	1/4	FTLR	all orchards
(Esteem 0.86EC)				Not registered
OFM pheromone	125 disp.	1	OFM	
(Isomate-M 100)				
(CheckMate OFM)				
spinosad	1/2 pt	1/2	PTB, OBLR,	WFT control is only
(Success)			WFT, FTLR	required on nectarines
				Katydids
acetamirpid	0.2 lb	1/2	OFM	Not registered
(Assail 70WP)				
or				
thiocloprid	1/4 pt			Not registered
(Calpso 4SC)				
imidacloprid	1/2 pt	1/4	TB	
(Provado 1.6F)				
methoxyfenozide	1 pt	1/2	PTB	Not registered
(Intrepid 2F)				
or				
Bacillus thuringiensis	1 lb		PTB,	
(Dipel 2X, others)			FTLR	
clofentezine	3/8 pt	1	TSSM, PSM	
(Apollo 4SC)				
or				
fenbutatin-oxide	1 lb			
(Vendex 50WP)				
or				
abamectin	1 pt			
(Agri-Mek 0.15EC)				
+ Horticultural oil at 0.25% by volume				

Table 8. Insecticide and Miticide Use in an OP-free IPM System with Emerging Technology on Peaches in the Northern San Joaquin and Sacramento Valleys

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
horticultural oil	4 gal	3/4	PTB, SJS,	Dormant application
+			ERM, BM,	would be applied to
esfenvalerate	3/4 pt		FTLR	all orchards
(Asana XL)				
or				
permethrin	1/2 pt			
(Pounce 3.2 EC)				
horticultural oil	4 gal	1/4	SJS, PTB	Dormant application
+			ERM, BM,	would be applied to
pyriproxyfen	1 pt	1/4	FTLR	all orchards
(Esteem 0.86EC)				Not registered
OFM pheromone	125 disp.	1	OFM	
(Isomate-M 100)				
(CheckMate OFM)				
acetamirpid	0.2 lb	1/2	OFM	Not registered
(Assail 70WP)				
or				
thiocloprid	1/4 pt			Not registered
(Calpso 4SC)				
spinosad	1/2 pt	1/4	PTB, OBLR	
(Success)			FTLR	
imidacloprid	1/2 pt	1/4	TB	
(Provado 1.6F)				
methoxyfenozide	1 pt	1/4	PTB,	Not registered
(Intrepid 2F)			FTLR, OBLR	
or				
Bacillus thuringiensis	1 lb			
(Dipel 2X, others)				
clofentezine	3/8 pt	1/2	TSSM, PSM	
(Apollo 4SC)				
or				
fenbutatin-oxide	1 lb			
(Vendex 50WP)				
or				
abamectin	1 pt			
(Agri-Mek 0.15EC)				
+ Horticultural oil at 0.25% by volume				

STRAWBERRIES

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California produces over 80% of the strawberries in the United States. The primary strawberry fruit growing regions of California are the south coast region including Oxnard Plain and the central coast region including Santa Maria Valley. The south coast region produces about 30% of the strawberry crop and the central coast region produces about 60% of the crop. The Central Valley and inland areas of Southern California produces less than 3% of the state crop. There is an important nursery industry in Northern California and parts of the Central Valley, but pest management of the nursery industry is not considered in this study. The twospotted spider mite is a key pest in all growing areas. Other insect pests of economic importance include: lygus bugs, cyclamen mites, root weevils, aphids, cutworms, beet armyworms, corn earworms, cabbage loopers, whiteflies, thrips and vinegar flies.

Twospotted and Cyclamen Mites

Twospotted spider mite (TSSM), *Tetranychus urticae*
Cyclamen mite (CM), *Phytonemus pallidus*

The major pest of strawberries in all growing areas is the TSSM, while the CM is an occasional, but important pest as well. CM is less of a problem in annual strawberry plantings. However, in multiple season plantings, CM can significantly reduce fruit production. TSSM are typically found on the bottom surface of strawberry leaves. Mating and egg laying behaviors are typically observed in all coastal strawberry growing regions year round. The highest mite populations are often observed following the spring fruit harvest and this peak is ordinarily followed by a rapid, natural decline in mite density due to harding-off of the leaves. TSSM damage is expressed as stippling, scarring, and bronzing of the leaves resulting in reduced plant vigor and may lead to plant death. TSSM feeding seriously interrupts photosynthesis and is particularly damaging during the first four to five months following transplanting, usually late summer, fall or early spring, depending on the growing region. Mite feeding during this critical period of plant growth can substantially reduce berry numbers per plant, as well as overall yield. Strawberry plants are less sensitive to mite feeding after initial berry set, but yield loss can be measured at all mite infestation levels exceeding one mite per leaflet.

TSSM populations may be reduced by maintaining vigorously growing plants. Also healthy plants can tolerate larger populations with less damage. Organophosphate (OP) and pyrethroid insecticides used to control other pests contribute to outbreaks of TSSM populations through the elimination of beneficial insects and mites. A winter application of a miticide such as abamectin (Agri-mek) or hexythiazox (Savey) followed by several in-season applications may be required to prevent damage. Alternating miticides with different modes of action slows the development of resistance to the miticides. However, this is difficult at present because relatively few effective miticides with different modes of actions are registered. Some growers routinely release predatory mites to augment biological control. However, these predatory mites are highly susceptible to OP, pyrethroid and carbamate insecticides used to control other pests. Growers utilizing predatory mites must be careful in their choice of pesticides and closely monitor TSSM populations. If damaging levels of TSSM are reached, populations should be treated.

Lygus Bugs (LB), *Lygus hesperus*

Lygus bugs are a serious pest in the central coast, and occasionally in the Central Valley and inland areas of Southern California. LB is rarely a pest in the southern coast region and Oxnard Plain, where the fresh market berry harvest is generally completed by the end of May. LB overwinter as eggs which hatch in March on weeds. Once they develop to adults, the adults migrate into the strawberry fields in late April. LB can also overwinter in second year strawberry plantations. LB is damaging as both adults and nymphs. They feed on developing berries causing reduced berry size/weight. Cat-facing is caused by puncturing individual seeds so that development stops in the area surrounding the feeding site. Cat-faced fruit can only be sold for juice or freezer market at a very low price relative to fresh berries. Since there is a very low threshold for LB in strawberries, the use of currently available beneficial insects for augmentative control is unfeasible. Control has relied on repeated applications of insecticides. Most OP applications in the central coast and Santa Maria growing areas target LB. Malathion (Malathion) and naled (Dibrom) are the primary OP insecticides used for LB control, but methomyl (Lannate), fenpropathrin (Danitol) and bifenthrin (Brigade) are also widely used. LB usually requires one to four insecticide treatments per growing season depending on region and pest pressure. Controlling LB on weeds, before the adults migrate to the strawberries, is an important cultural method of reducing LB densities. LB adults have developed resistance to many registered insecticides and control can be very difficult.

Other Common Pests

The larvae of many root-feeding weevils are significant strawberry pests worldwide but have largely been eliminated as pests in California by pre-plant soil fumigation and annual plantings. Once methyl bromide is banned from use, the root-feeding weevils become more significant pests. The most common weevils that are found in California strawberry fields inclue the cribrate weevil, the black vine weevil and the Fuller rose beetle. The black vine weevil and the Fuller rose beetle are less important than the cribrate weevil. Flightless adults emerge from the soil in late spring or summer with peak populations occurring in summer and early fall. Eggs are laid in the soil or around the plant crown approximately one month after the adult emerges. The most serious damage occurs as a result of larval feeding. Larvae feed on root hairs and may remove the bark and cortex off larger roots. Infestation often occurs in circular areas surrounding egg-laying sites and can be seen as plants begin to wilt and die. Root weevils occur on occasion in unfumigated strawberry fields in a few central coast locations. Another root beetle, Hoplia, can be a serious pest in unfumigated fields in the Central Valley. Once populations have been established, root beetles are extremely difficult to control. One of the few possible controls at this point is chlorpyrifos (Lorsban) soil drenching.

Melon and strawberry aphids are the most common aphid species found on strawberries, although the green peach aphid and potato aphid can also infest strawberry plants. Aphid populations usually reach peak densities during late January or February but may continue to increase during the spring when temperatures are moderate. Populations undergo a natural decline to very low levels during May and June. Aphid damage is the result of sooty mold that develops on the aphid honeydew. Aphids rarely reach economically damaging levels in commercial fields. If a damaging population is found, a single application of Dibrom, Malathion or diazinon (Diazinon) can be used for control.

Beet armyworms and cutworms cause problems by feeding on the crown of a strawberry plant in the early season. These species as well as corn earworms and cabbage loopers feed on fruit as well as leaves later in the season. Lorsban, and to some extent Diazinon and carbaryl (Sevin), are used for their control. Various strains of *Bacillus thuringiensis* (Bt) can be effective for control of early instar larvae. However, to ensure the most effective level of control, careful attention must be paid to achieving good coverage and to the selection of a subspecies of Bt.

Whiteflies, particularly the greenhouse whitefly, have become serious problems in a few growing areas, particularly where second year plantings or alternative whitefly hosts are present. Malathion and Diazinon are used alone or in tank mixes for whitefly control and several applications are often needed for control. Imidocloprid (Admire/Provado) is now available through an emergency registration. Western flower thrips is a concern for central coast growers because of potential fruit bronzing. Thrips are occasionally treated with Malathion and Dibrom. Lannate is probably a more effective control material, but its use is limited by longer harvest intervals.

Vinegar flies typically cause problems late in the season on fruit being picked for processing, particularly in Southern California. Multiple applications with short residual materials for control of adult flies is necessary to protect fruit, depending on the length of the processing harvest period. Reducing harvest intervals and removing old berries from fields and packing sheds are good cultural controls for vinegar flies. However shortening the harvest intervals is costly relative to the low returns from processing berries.

Current - Pest Management Program

South Coast Region

The south coast region includes Los Angeles, Orange, San Diego and Ventura counties. TSSM is of serious concern in the south coast region from January to early March since high mite populations can lead to yield reduction. Cultural practices and biological control can be used to suppress TSSM. However, cultural practices or biological control is often insufficient to maintain TSSM populations below damaging levels and treatments are necessary. In 1999, Agri-Mek and Savey were each applied to about 35% of the south coast region acreage (Table 1). Although registered for use on TSSM, Brigade and Danitol are not typically used for TSSM control but are recommended for control of LB. Brigade was applied to 6% and Danitol was applied to over 9% of south coast acreage presumably for a complex of different insects. LB is not a common pest of strawberry in Southern California.

Although root weevils have largely been eliminated as pests in California by pre-plant soil fumigation and annual plantings, they are most common in unfumigated fields. A fall Lorsban soil drenching is one of the few possible controls. Applications of Lorsban can be targeted toward many pests, but it is critical for weevil control in Southern California. Lorsban was applied to approximately 28% of south coast strawberry acreage.

There are a number of lepidopteran pests of strawberries that can be major pests in the southern growing regions. Control of lepidopteran pests relies on Bt and/or a combination of Bt with Lannate where whitefly and/or thrips are problems. Bt was applied to over 92% of the acreage and Lannate was applied to 13% of the total acreage. Control of early season armyworm and cutworm feeding in the crown of the strawberry plants relies on Sevin, Lorsban and Diazinon. Sevin bait is applied to strawberry beds around the base of the plants. Unlike carbaryl foliar sprays, bait applications are not destructive to beneficial insects. Sevin bait is important for control of cutworm and is most effective if applied at night, when cutworms are more active. Lorsban, Diazinon and Sevin was applied to approximately 28%, 2% and 13% of the strawberry acres, respectively.

Vinegar flies cause problems late in the season on fruit being picked for processing. Multiple applications with short residual materials such as Malathion and Dibrom are used for control of adult flies. Malathion was applied on about 28% of the acreage and Dibrom on about 1% of the acreage.

Central Coast Region

The central coast region includes Monterey, Santa Barbara, San Benito, San Luis Obispo, Santa Clara and Santa Cruz counties. LB is a major pest of central coast strawberries. Strawberries in the central coast are typically grown through the summer months. Chemical treatment should target first instar nymphs since older nymphs and adult LB are more difficult to control. Malathion and Dibrom are the most commonly applied insecticides for LB control. These insecticides are applied immediately after LB hatch and require multiple applications. Malathion is applied on average 1.8 times to the strawberry acreage while Dibrom is used on about 68% of the acreage (Table 2). Dibrom typically provides good late season control, but it should not be used when temperatures exceed 85°F due to the potential for plant phytotoxicity. Pyrethroids are the most effective insecticides currently registered for LB control in strawberries. However, these insecticides will disrupt biological control and may result in TSSM outbreaks. Danitol was applied to over 28% of strawberry acreage while Brigade was applied to over 17% of the strawberry acreage.

TSSM and CM are of serious concern in the central coast region. CM has become a less significant pest as strawberry fields shift to annual plantings. Cultural practices and biological control to suppress TSSM is ideal, however it is often insufficient to maintain mite populations below damaging levels and treatments are necessary. Agri-Mek was applied on average one time per season. Dicofol (Kelthane) was applied to over 11% of the acreage in this region and is very effective against CM. Kelthane is applied with a wetting agent in 400-600 gallons of water. Kelthane is toxic to predaceous mites, but is relatively nontoxic to other beneficial insects.

Thrips are occasionally treated with Malathion and Dibrom. Lannate is a more effective control material, but its use is limited by a longer pre-harvest interval. Lannate has a 10 day pre-harvest interval for fruit sold for processing as compared to a 3 day pre-harvest interval for fruit to be sold for fresh market. Fruit sold for processing are an economically important supplement to fresh market production.

There are a number of lepidopteran pests of strawberry that can be major pests in the central growing regions. Control of lepidopteran pests relies on Bt and/or combination of Bt with Lannate. About 100% of the acreage was treated with Bt while about 77% of the acreage was treated with Lannate. Control of cutworm relies on Sevin bait applied to strawberry beds around the base of the plants. Sevin bait, which is less harmful to beneficials, is a very important tool for control of cutworm and is most effective if applied at night when cutworms are more active. Sevin was applied to approximately 30% of strawberry acres.

In the 1950s, prior to the use of methyl bromide (Methyl Bromide), root weevils were major economic pests in strawberry. Soil fumigation with Methyl Bromide and chloropicrin (Telone) for weed and disease control has greatly reduced the damage of root weevils. However, with the impending loss of Methyl Bromide as a soil fumigant, the root weevils may once again become major strawberry pests. Root weevils are important pests in other states where replant oil fumigation is not practiced. Further, none of the currently registered insecticides will provide effective control of weevil larvae. When root weevils occur in unfumigated fields, a fall soil drench application with Lorsban is one of the few possible controls.

OP Free – Pest Management Program with Available Technology

Eliminating OP insecticides from the strawberry production will have differential impacts in the various production regions. In the south coast region the impact of the loss of OP insecticides would be minimal as long as pre-plant fumigation remains an option for grower. It is anticipated that there would be no significant yield loss over current levels with the loss of OP insecticides. In the south coast region about 2/3 of the acreage would receive only one OP insecticide and 1/3 of the acreage would receive no OP insecticide applications (Table 3). The two most important OP insecticides are Lorsban and Malathion. Lorsban is used for early season cutworm and beet armyworm control and for spot treatment of root weevils. Malathion is used for vinegar fly and LB control. Without OP insecticides, early season cutworm and armyworm would rely on increased use of Sevin bait and Bt. Control of LB and vinegar flies would rely on Brigade, Danitol and Lannate. However, LB is not a major pest in the south coast region. The major pest of strawberry in the south coast region is TSSM and control would remain similar to current control procedures but may increase if the use of pyrethroid insecticides and Lannate replaces the OP insecticides. All strawberry acreage would receive an Argi-Mek application with about a quarter of the acreage receiving a Savey application.

In the central coast region about 1 and 1/2 applications of OP insecticides are applied to all acreage (Table 4). The major pest targeted with OP insecticides is LB; the elimination of Malathion and Dibrom for LB control would increase grower dependence on Danitol and Brigade. Danitol and Brigade are effective for control of TSSM as well as LB but TSSM resurgence often occurs several weeks after applications of Danitol or Brigade. Outbreaks of TSSM are possible and additional miticide applications would be required for TSSM control.

Without new registrations of pesticides for LB control, the repeated use of Danitol and Brigade would likely result in the rapid development of resistance in both LB and TSSM populations

Eliminating OP insecticides from the strawberry production in the central coast region would increase the use of Lannate for control of greenhouse whiteflies and thrips. The use of Lannate may result in increased secondary pest populations through the elimination of beneficial insects. In addition, the use of Lannate would prevent berries from being sold for processing because of the longer pre-harvest interval for processing strawberries as compared to fresh market strawberries. The section 18 registration of Provado for whiteflies offers a less disruptive alternative, but Provado is more expensive and less effective than Lannate. It is anticipated that there would be no significant yield loss over current levels with the loss of OP insecticides in the near future.

OP Free – Pest Management Program with Emerging Technology

The IPM programs below were constructed with currently registered insecticides and/or insecticides that are anticipated to be registered within four to five years and technologies that would require a greater reliance on cultural and biological alternatives. The IPM program with emerging technology would produce a stable long-term program that would allow for much greater impact of beneficial insects and mites on the pest populations. Cultural practices that could be incorporated would be mandatory annual plantings to break the life cycles of certain pest species such as whiteflies and soil borne insects, increased attention to field sanitation coupled with shortened harvest intervals and the use of trap crops.

In the south coast region, the major pest is the TSSM. Control of the TSSM would rely on predator mite releases and compatible selective miticides such as spirodiclofen (Envidor) and etoxizole (Table 5). Lepidopteran pests would be controlled with either of two reduced risk insecticides, methoxyfenozide (Intrepid) or spinosad (Success). Intrepid provides excellent control of lepidopteran pests while Success provides excellent control of both lepidopteran pests and thrips. Registration of these insecticides is expected within a few years. The registration of Intrepid and Success would significantly reduce the use of Bt.

LB is a minor pest in the south coast region and can be controlled by a number of reduced risk neonicotinoid insecticides. The two neonicotinoid insecticides that are near registration are Provado and thiamethoxam (Actara). However, there are a number of neonicotinoid insecticides currently under development and their registration is expected within five years. Beside LB control these insecticides also provide excellent control of whiteflies and aphids. Buprofezin (Applaud) also provides effective alternatives for control of whiteflies and aphids. However, Applaud would not be used when LB is a problem.

In the central coast region, the major pest is LB and control would rely on trap crops (legumes, mustard etc.) to reduce the overall population combined with neonicotinoid insecticides such as Provado or Actara. Sole reliance on neonicotinoid insecticides would require repeated applications that would eventually lead to resistance. Thus the use of cultural control methods such as trap crops would be essential to maintain the viability of these new insecticides over time. Beside LB control these insecticides also provide excellent control of whiteflies and aphids. It is projected that Applaud, which provides effective control for whiteflies and aphids, would not be widely used in the central coast region because of the use of neonicotinoid insecticides. Lepidopteran pests would be controlled with either of two reduced risk insecticides, Intrepid or Success. To complete an IPM program with emerging technology would require the registration of effective yet selective miticides, such as Endivor or etoxizole that would be compatible with predator mite releases.

Addendum

A new miticide, bifenazate (Acramite), has been registered in strawberry since the economic analysis. Acramite will be added to the existing arsenal of miticides, e.g., dicofol (Kelthane), Savey (hexythiazox) and abamectin (Agri-Mek). Acramite provides a new mode of action and broadens the base of miticides. This should stabilize or slow the development of miticide resistance and hopefully reduce miticide costs. This new product is positive for strawberry IPM in that it is not disruptive to natural enemies.

Table 1. Insecticide and Miticide Use on Strawberries in the South Coast Region of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
abamectin (Agri-Mek)	145	7,969	35.5	$727,913
azadirachtin (Neemix)	15	719	3.2	$17,652
Bacillus thuringiensis (Various Products)	2,144	17,351	77.2	$66,202
Bacillus thuringiensis encapsulated-delta-endotoxin (MVP II)	1,690	3,533	15.7	$30,023
bifenthrin (Brigade)	167	1,407	6.3	$34,978
carbaryl (Sevin)	5,374	3,001	13.4	$37,404
chlorpyrifos (Lorsban)	5,869	6,326	28.2	$111,040
clarified-neem-oil (Neem)	2,777	1,088	4.8	$5,554
diazinon (Diazinon)	361	388	1.7	$3,338
dicofol (Kelthane)	175	162	0.7	$4,921
fenbutatin-oxide (Vendex)	196	141	0.6	$10,866
fenpropathrin (Danitol)	572	1,926	8.6	$32,173
hexythiazox (Savey)	1,396	7,704	34.3	$614,332
horticultural mineral oil (Various Products)	1,770	35	0.2	$974
imidacloprid (Admire)	841	1,682	7.5	$286,264
malathion (Malathion)	10,759	6,355	28.3	$58,852
methomyl (Lannate)	2,483	2,900	12.9	$55,183
naled (Dibrom)	168	166	0.7	$1,755
pyrethrins (Pyrenone)	4	396	1.8	$6,208

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre planted for the south coast region is about $93.68.

Table 2. Insecticide and Miticide Use on Strawberries in the Santa Maria and Central Coast Region of CA, 1999

Material*	**Lb (ai)**	**Acres Treated**	**% Acres Treated**	**Costs**
abamectin (Agri-Mek)	371	22,951	116.5	$1,858,168
azadirachtin (Neemix)	28	611	3.1	$32,340
azinphos-methyl (Guithion)	458	553	2.8	$9,518
Bacillus thuringeinesis (Various Products)	1,449	19,513	99.8	$44,731
Bacillus thuringeinesis encapsulated-delta-endotoxin (MVP II)	16	36	0.2	$283
bifenthrin (Brigade)	347	3,480	17.7	$72,948
carbaryl (Sevin)	7,610	5,787	29.4	$52,968
chlorpyrifos (Lorsban)	1,758	1,857	9.4	$33,252
clarified-neem-oil (Neem)	102	40	0.2	$203
diazinon (Diazinon)	2,320	2,804	14.2	$21,441
dicofol (Kelthane)	2,322	2,231	11.3	$65,281
fenbutatin-oxide (Vendex)	7,809	774	3.9	$44,747
fenpropathrin (Danitol)	1,540	5,455	27.7	$86,635
hexythiazox (Savey)	1,777	9,801	49.8	$781,915
horticultural mineral oil (Various Products)	8,064	1,905	9.7	$4,435
imidacloprid (Admire)	176	372	2	$59,936
malathion (Malathion)	65,697	35,233	178.9	$359,360
methomyl (Lannate)	12,852	15,137	76.9	$285,572
naled (Dibrom)	13,005	13,297	67.5	$136,166
pyrethrins (Pyrenone)	44	1,605	8.2	$71,072

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre planted for the Central and Northern coast region is about $204.15

Table 3. Insecticide and Miticide Use in an OP free Pest Management Program with Available Technology on Strawberries in the South Coast Region

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
abamectin (Agri-Mek 0.15 EC)	16 oz	11/2	TSSM	
hexythiazox (Savey 50WP)	4 oz	1/2	TSSM	
dicofol (Kelthane 35WP)	3 lb	1/20	CM	
Bacillus thuringiensis (Dipel DF)	1.0 lb	1	Armyworms, leafrollers tomato fruitworm	
Encapsulated delta endotoxin (MVP II)	32 oz	1/2	Armyworms, tomato fruitworm	
carbaryl (Sevin 5% bait)	30 lb	1/2	Cutworms	Preventative treatment early in season
imidacloprid (Admire 2F)	32 oz	1/7	Whiteflies	Section 18 registration
bifenthrin (Brigade WSB)	2 lb	1	LB, vinegar flies	May results in spider mite outbreaks
or				
fenpropathrin (Danitol 2.4 EC)	20 oz			
methomyl (Lannate SP)	1.0 lb	1	White flies, thrips, vinegar flies, and LB	Disrupts predation and parasitism

Table 4. Insecticide and Miticide Use in an OP free Pest Management Program with Available Technology on Strawberries in Santa Maria and the Central Coast Region

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
abamectin (Agri-Mek 0.15 EC)	16 oz	2 1/2	TSSM	
hexythiazox (Savey 50WP)	4 oz	1/2	TSSM	
horticultural oil (Omni Supreme)	2 gal	1/20	TSSM	Winter treatment only; can be phytotoxic
dicofol (Kelthane 35WP)	3 lb	1/8	CM	
Bacillus thuringiensis (Dipel DF)	1.0 lb	1	Armyworms, leafrollers	
carbaryl (Sevin 5%bait)	30 lb	1/4	Cutworms	Preventative treatment early in season
imidacloprid (Admire 2F)	32 oz	1/7	Whiteflies	Section 18 registration
bifenthrin (BrigadeWSB)	2 lb	2	LB	May result in spider mite outbreaks
or				
fenpropathrin (Danitol 2.4EC)	20 oz	2		
or				
methomyl (Lannate SP)	1 lb	3	LB, thrips	Disrupts predation and parasitism

Table 5. Insecticide and Miticide Use in an OP free Pest Management Program with Emerging Technology for Strawberries in the South Coast Region

Tactic	**Rate Form./ac**	**# Appl./ Season.**	**Pest**	**Notes**
abamectin (Agri-Mek 1.5EC)	16 oz	2	TSSM	Not registered
or				
milbemectin (Mesa)	32oz	1		Not registered
Predator mites	10,000	5	TSSM	
spirodiclofen (Envidor 2SC)	18 oz	1	TSSM	Not registered
or				
etoxizole (Not Named 50W)	1/4 lb	1		Not registered
imidacloprid (Provado 1.6 F)	20 oz	1	LB, aphids, whiteflies	Section 18 registration
or				
thiamethoxam (Actara 25WP)	1 lb	1		Not registered
buprofezin (Applaud 70W)	0.5 lb	1	Whiteflies, aphids	Not registered
field sanitation	--	--	Vinegar fly	Destroy old fruit when temperature is warm
spinosad (Success 2SC)	8 oz	2	Lepidopteran, pests, thrips	Not registered
or				
methoxyfenozide (Intrepid 2F)	8 oz	2	Lepidopteran pests	Not registered

Table 6. Insecticide and Miticide Use an OP free Pest Management Program with Emerging Technology for Strawberries in the Central Coast Region

Material/tactic	**Rate Form/ac**	**# Appl/ Season**	**Pest**	**Notes**
abamectin (Agri-Mek 1.5EC)	16 oz	1	TSSM	
or				
Predator mites	10,000	8		
narrow range oil (Omni Supreme)	2% by vol.	1/20	TSSM	Winter treatment only; can be phytotoxic
spirodiclofen (Envidor 2SC)	18oz	1	TSSM, CM	Not registered
or				
etoxizole (No Name 50W)	1/4 lb	1		Not registered
Trap crops-Legumes		1	LB	
imidacloprid (Provado 1.6 F)	10 oz	3	LB, aphids whiteflies	Section 18 registration
or				
thiamethoxam (Actara 25WG)	0.5 lb			Not registered
field sanitation	--	--	Vinegar flies	Destroy old fruit when temperature is warm
spinosad (Success 2SC)	8 oz	1	Lepidopteran pests, thrips	Not registered
or				
methoxyfenozide (Intrepid 2F)	8 oz		Lepidopteran pests	Not registered

TOMATOES (FRESH AND PROCESSED)

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California produces over 90% of processing tomatoes in the United States and the Central Valley produces over 95% of California's crop. Processing tomatoes are grown on over 315,000 acres. In addition California produces over 30% of fresh market tomatoes in the United States and the Central Valley produces over 75% of California's crop with about 20% of the crop in the coast and about 5% in the lower desert. Fresh market tomatoes are grown on over 60,000 acres. There are numerous insect and mite pests that attack both processing and fresh market tomatoes and can result in significant damage in most seasons if not controlled. The major insect and mite pests of tomato are lepidopterous larvae, stink bugs, aphids, leafminers and russet mites.

Primary Lepidopterous Pests

Tomato Fruitworm (TFW), *Helicoverpa* (*Heliothis*) *zea*
Beet Armyworm (BAW), *Spodoptera exigua*
Tomato Pinworm (TPW), *Keiferia lycopersicella*

TFW and BAW infest tomatoes throughout the state and typically require one or more insecticide applications to achieve adequate control. TPW is a problem for tomato growers in southern California including the southern San Joaquin Valley and the coastal growing region. While all three lepidopterous pests can feed on foliage, the damage occurs with feeding directly on developing and mature fruit. TFW larvae prefer to infest green fruit and will enter near the stem shortly after hatching. Single TFW larva can develop completely within the fruit molting four or five times before exiting to pupate in the soil. Damaged fruit will ripen prematurely and often develop mold that can rot fruit prior to harvest. Early in the season, when tomatoes are small (<0.75 in), a single TFW larva may damage several tomatoes before completing development. If no fruit is available, larvae will feed on terminal foliage and may bore into stems. Late-season infestations are especially difficult to identify because of the small entry sites left by young larvae. Late-season infestations may contaminate both fresh market and processing tomatoes. An important component of TFW management is natural enemies especially the larval parasitoid *Hyposoter exiguae* and the egg parasitoid *Trichogramma pretiosum* in southern California while in the San Joaquin and Sacramento valleys the larval parasitoid *Hyposoter exiguae*, a complex of *Trichogramm* spp, and various general predators such as minute pirate bug, *Orius* spp., and bigeyed bugs, *Geocoris* spp., are important natural enemies. However, *Hyposoter exiguae* do not kill the larvae until the TFW has entered the fruit and *Hyposoter exiguae* cocoons remain in the fruit as contaminants. Since natural enemies cannot consistently prevent damage, growers rely primarily on multiple applications of insecticides for control of TFW. Insecticide applications target newly hatched larvae before they enter the fruit since TFW that have entered fruit are very difficult to control and have already damaged the fruit.

BAW is found throughout the state and can be as damaging as TFW. Eggs are laid in scale-covered clusters on leaves and adjacent weed hosts such as redroot pigweed and nettleleaf goosefoot. A single cluster may consist of as many as 100 or more eggs. Emerging young feed together near the egg cluster primarily on foliage and eventually disperse as they grow. This foliage feeding causes little or no damage to mature plants, but may kill young plants. As the season progresses newly hatched BAW may enter and develop within fruit causing the same kind of damage as TFW. Typically BAW will not feed on fruit until the third or fourth instar causing mostly external damage. These older larvae cause the most extensive damage to fruit. The feeding damage is usually shallow holes that often scar over as the fruit matures. Such damage is mostly superficial, but results in unmarketable fresh market tomatoes and in whole pack processing tomatoes. Under certain conditions, BAW feeding may leads to secondary infections by molds and fungus that rot fruit rendering them unusable even for processing. An important component of BAW management is natural enemies especially the larval parasitoid *Hyposoter exiguae* and various general predators such as minute pirate bug, *Orius* spp., and bigeyed bugs, *Geocoris* spp., along with nuclear polyhedrosis virus. Egg parasitoids are not an effective control agents of BAW because the egg mass is protected by its scale covering. Once large populations have developed growers rely on broad-spectrum insecticides for BAW control.

Unlike TFW and BAW, which are serious pests throughout the state, TPW is a problem for growers in the southern San Joaquin Valley and southern California. TPW does not have a diapause and there are as many as eight overlapping generations. A generation can occur in as little as a month. Larvae can damage tomato plants and fruit at any period and become a more significant pest as the season progresses. Soon after emerging, females lay single eggs on the lower surface of leaves. Young TPW larvae (first and second instar) feed within leaf tissue creating blotchy mines and folding leaves over with silk. This damage is of little concern in mature plants, but can damage seedlings or transplants. Significant losses result from larval feeding within tomatoes. Larvae will enter both ripe and unripe fruit, usually near the stem or under the calyx. They bore tiny, dry, shallow tunnels throughout the core leaving behind brown and black frass that may exude from the outer edges of the calyx. Where abundant, 100% of fruit may be infested. Areas that plant and harvest more than one tomato crop per year (e.g. south coastal fresh market tomatoes) are especially susceptible to infestation from populations established during the first crop. Populations can explode leading to severe defoliation and nearly 100% fruit infestation if not managed. Large populations require repeated chemical applications through harvest to control TPW. Long-term TPW control relies on comprehensive sanitation of old tomato plants and other solanaceous host combined with a minimum of three months host-free period.

Secondary Lepidopterous Pests

Yellowstriped Armyworms (YAW), *Spodoptera ornithogalli* and *S. praefica*
Cabbage and Alfalfa Loopers (loopers), *Trichoplusia ni* and *Autographa californica*
Tomato and Tobacco Hornworms (hornworms), *Manduca quinquemaculata* and *M. sexta*

The YA, loopers, and hornworms are only occasional pests of tomatoes, although YA can be a very serious pest of tomato, with periodic outbreaks occurring every few years. YA look and behave in a very similar manner as BAW, but tend to grow larger, cause more damage, and are generally harder to control. Damage to tomatoes closely resembles that of BAW with shallow irregular holes. Damage increases during the season with the greatest amount of damage occurring in late summer. Alfalfa loopers are confined to the mild coastal growing region while cabbage loopers are much more wide spread and can be found in most tomato fields every year. Both are predominantly foliage feeders causing large irregular holes in mature leaves. While these loopers rarely occur in large enough numbers to cause significant damage, at times large populations of loopers can retard the growth of young plants or expose fruit to sun damage in mature plants. Loopers are easily controlled with a number of insecticides. Hornworms are also relatively unimportant pests although they can build up to damaging levels in warm inland areas. Voracious feeders, hornworm larvae will consume leaves, stems, and also attack green fruit. Like loopers, hornworms are relatively easy to control using several pesticides. However, loopers and hornworms seldom require treatment since they are typically under good biological control and insecticide treatments used to control primary lepidopterous pests will generally eliminate any threat from these pests.

Stink Bugs

Consperse Stink Bug, *Euschistus conspersus*
Southern Green Stink Bug, *Nezara viridula*
Say's Stink Bug, *Chlorochroa sayi* or *Pitedia sayi*
Redshoulded Stink Bug, *Thyanta pallidovirens*
Uhler’s Stink Bug, *Pitedia uhleri*

Stink bugs vary in color from brown to green, with all species sharing the similar biology and causing similar damage to tomatoes. In the San Joaquin and Sacramento Valleys, stink bugs are one of the most significant threats to both fresh market and processing tomatoes. Fields located near creeks and sloughs may experience increased stink bug damage along bordering edges. Neighboring weedy areas, orchards with heavy vegetative cover crop and blackberry in particular are known to host overwintering populations of stink bugs. Damage usually takes the form of small, dark pinpricks surrounded by areas of discoloration that are yellow on green fruit and green on ripe fruit. Stink bugs damage tomatoes by piercing the surface of fruit with their mouthparts and secreting enzymes that break down fruit tissue. These enzymes remain active long after the stink bug has stopped feeding and leaves the tissue below the feeding site white, dry and spongy. In some cases yeast and other microbes are introduced along with digestive enzymes. These secondary infections often lead to rapid decay and can quickly spread throughout a field leading to significant economic losses. Once stink bugs have established in tomato fields they are particularly difficult to control. Stink bugs are cryptic and if disturbed they will usually drop to the ground and hide. This can make it easy to overlook incipient populations. The irregular blotches left behind after feeding are usually the easiest way to identify imminent stink bug outbreaks, but by this point significant economic damage will have already been realized particularly in fresh market tomatoes. Naturally occurring egg parasites are common, but are most effective in controlling the introduced Southern green stink bug. Parasitism is more useful in processing tomatoes intended for juice or paste, which can tolerate moderate stink bug damage. In fresh market or whole peel processing tomatoes chemical treatment is essential once damage thresholds are reached to achieve satisfactory control.

Aphids

Potato Aphid (PA), *Macrosiphum euphorbiae*
Green Peach Aphid (GPA), *Myzus persicae*

PA is considered the more important of the aphid species attaching tomatoes. Aphid species suck nutrients from the phloem of tomato plants leaving behind deposits of honeydew and cast skins. If populations are large, aphid feeding can stunt seedling or transplant growth and honeydew deposits can encourage sooty mold. The PA is generally more common throughout the state compared to GPA due to its tolerance to high temperatures. Large populations typically build up in late summer across the Central Valley reducing fruit set and forcing blossom drop. GPA is usually limited by warm weather to the coastal growing region. In the early spring, GPA often occurs on seedlings where they may cause plants to wilt and delay maturation. The real concern with GPA, especially in southern California, is its ability to act as a vector for viruses such as tomato yellow top and alfalfa mosaic. Insecticide applications directed against other pests often control aphid populations. It should also be noted that insecticides have not been shown to prevent disease transmission by aphids.

Leafminers

Serpentine Leafminer (SL), *Liriomyza trifolii*
Vegetable Leafminer (VL), *L. sativa*
Pea Leafminer (PL), *L. huidobrensis*

Leafminers are tiny flies that share a similar morphology, biology and a presence throughout California on numerous weeds and crops. With a life cycle that lasts as little as two weeks and as many as ten generations per year, populations can build up remarkably fast. Adult leafminers lay single eggs within the leaf tissue. Emerging larvae develop within the leaf tissue creating white, slender, meandering mines. Under a heavy leafminer population these mines can weaken tomato plants leading to defoliation, smaller fruit size, reduced overall yield and may expose fruit to sunburn. If severe, infestations will kill plants and may destroy entire fields. Any cultivar having a long fruiting period (e.g. most fresh market varieties and pole tomatoes) will be especially vulnerable to infestation. Leafminers are kept under control by beneficial insects especially the parasitoid, *Diglyphus begini*. Leafminer populations will often explode late in the season following applications of broad-spectrum insecticides intended for lepidopterous pests control, but which also kills parasites. If chemical control measures are required, it is important to identify the leafminer species since SL is more difficult to control than the VL or PL. Accordingly, the potential of resurgence is more likely with SL than for VL or PL.

Tomato Russet Mite (TRM), *Aculops lycopersici*

TRM are small (1/100 in), conical shaped mites that are yellow to pink in color and occur in all growing regions of California. Usually appearing in mid to late summer, TRM are often carried by wind from adjacent weeds that serve as winter hosts (e.g. nightshade, jimsonweed, and other other solanaceous weeds) or they may be present on greenhouse transplants. TRM pass through two nymphal stages before becoming adults. In hot weather they can complete their development within a week. Infestations often start near the ground, at the stem, when fruit are about 1 inch and work their way up onto leaves. As populations build stems and leaves may appear greasy and change to bronze in color. This damage may lead to severe defoliation, which exposes developing fruit to sunburn and contributes to crop loss. Under dry, hot conditions TRM can kill plants within a few days. Because of their extremely small size they are typically not noticed until some amount of damage is apparent. This fact combined with the ability of TRM to develop quickly, means growers must be vigilant and treat at the onset of infestations. A single application of sulfur dust or wettable sulfur can control moderate TRM populations and it is often applied preventatively due to the difficulty in monitoring developing populations. Sulfur is most effective during the hot weather conditions conducive to TRM outbreaks, however there is a risk of phytotoxicity at temperatures above 95° F and during periods of high humidity. Use of broad-spectrum insecticides such as pyrethroids can reduce or eliminate natural enemies of mites, especially predatory mites, thus they should be avoided or used sparingly in areas where TRM are likely to become problematic.

Seedling Pests

Cutworms (CW), Variegated *Peridroma saucia*, Black *Agrotis ipsilon*, and others
Flea Beetles (FB), *Epitrix hirtipennis* and other species
Wireworms (WW), *Limonius* spp.
Garden Symphylans (GS), *Scutigerella immaculata*.

Several pests can attack recent transplants or emerging seedling tomatoes leading to economic losses if proper control measures are not taken. Some pests include the CW, FB, WW and GS. Seedling pests pose a greater economic threat to transplanted fields, which start out with a reduced stand compared to direct seeded fields. Given the tendency of transplanting most (90%) fresh market tomatoes, growers must carefully monitor fields to prevent the need for costly re-planting. In addition to direct damage, these pests may also introduce seedling diseases. These pests are infrequent in most tomato fields. Under heavy infestations a single treatment is usually enough to eliminate significant losses. In some cases border or spot treatments will control the seedling pests.

The most prevalent seedling pests throughout the tomato growing regions of California include the CW and FB complexes. CW are large (~1-2 in) lepidopterous larvae. CW are nocturnal and hide in the soil during the day. These pests are typically associated with fields rich in plant material, e.g. crop residue left behind after harvest of previous plantings. CW larvae feed on young tomato plants at the soil line. Since CW are active only by night, control measures should be applied at night.

Several species of FB are common pests throughout the state and are likely to be found in most early plantings of tomatoes. It is these early spring plantings that are particularly vulnerable to FB infestations. Adult FB chew small holes in the leaves and occasionally into stems weakening young plants, impairing growth, and eventually killing them under heavy infestations. This is especially true soon after thinning or at transplanting when there are a reduced number of plants. While these pests will feed on foliage throughout the season, their effect is significant only in very young plants or under hot windy conditions that can dry-out damaged plants. If FB populations become a problem, a single insecticide application is usually all that is required to achieve economic control.

Current Pest Management Program

Processing Tomatoes in the Central Valley

The Central Valley (Fresno, Kern, Kings, Madera, Tulare, Merced, San Joaquin, Stanislaus, Butte, Colusa, Glenn, Placer, Sacramento, Solano, Sutter, Tehama, Yolo and Yuba counties) produces about 99% of California's processing tomatoes, with about 65% of production in the northern San Joaquin Valley and the Sacramento Valley and about 35% of the production in the southern San Joaquin Valley. However production of processing tomatoes has been moving more to the southern San Joaquin Valley from the Sacramento Valley. There is a very small amount of processing tomatoes in the lower deserts. There are over 310,000 acres of processing tomatoes in California. A vast majority (about 90%) of processing tomatoes are direct seeded with plantings taking place throughout the first half of the year and harvests usually ending by mid-October. Harvest of desert production is usually completed by July, allowing processing facilities in the Central Valley to prepare for the crop. Processing tomatoes in California are used for making a diversity of products. The intended use of a processing tomato crop has broad implications towards the insect pest management strategy employed. Certain kinds of insect damage, e.g. stink/lgyus bug, that are acceptable on tomatoes destined for paste or juice production would lead to down-grading or even rejection for whole peel use. This has a direct effect on insecticide use patterns and other management techniques employed by growers. The following provides information on current insecticide use patterns for the Central Valley.

A combination of broad-spectrum insecticides make up the four predominant insecticides used on processing tomatoes. In 1999, an average of two insecticide applications for all uses were applied to processing tomatoes. Dimethoate (Dimethoate) was the most commonly applied insecticide, with over 54% of the total acreage treated at a typical application rate of 0.5 lbs ai per acre. The combined systemic and contact activity of Dimethoate makes it useful in controlling both aphids and stink bugs. However, Dimethoate may increase the threat from leafminers since Dimethoate disrupts the biological control of leafminers that help limit leafminer populations. For aphid control, Dimethoate offers an economical alternative to the more expensive but less disruptive neonicotinoid imidacloprid (Provado), which was used on less than 3% of the processing tomato acreage. Stink bugs are one of the most difficult pests to control. Tomatoes damaged by stink bugs are considered unacceptable for use in whole peel processing, but some damage may be acceptable for other uses. Recurrent problems with stink bugs throughout the Central Valley also accounts for the heavy use of Dimethoate. Stink bugs are also controlled by a combination of methamidophos (Monitor), esfenvalerate (Asana) and methomyl (Lannate) or *lambda*-Cyhalothrin (Warrior).

The pyrethroid insecticides (Asana, Warrior and cyfluthrin (Baythroid)) were used on over 50% of the processing tomato crop in the Central Valley. These products provide effective control, or at least suppression, for a number of major fruit and foliage pests found on processing tomatoes. The pyrethroid insecticides suppress the lepidopterous larval complex, stink and lygus bugs, and some seedling pests. Lannate, a carbamate insecticide, was applied to about a quarter of the processing tomato acreage in the Central Valley. Typically applied at a rate of 0.45 to 0.90 lbs ai per acre, tomato growers use Lannate for control of the major lepidopterous pests including armyworms and TP and in combination with Asana or other pyrethroid insecticides for stink bug control. Like Dimethoate, Lannate is known to induce flare-ups of leafminers. Leafminers are a late season pest of processing tomatoes and are usually the result of repeated applications of broad-spectrum insecticides that eliminate the leafminer's primary parasitoid *Diglyphus begini*. Spinosad (Success) provides excellent control of the majority of lepidopterous pests. Moreover, Success also effectively controls leafminers while simultaneously preserving their natural parasites. However, like Provado, Success is relatively expensive, which limits its use in processing tomato. Success was used on about 5% of the acreage in 1999. *Bacillus thuringiensis* (Bt) was used for control of lepidopterous pests on nearly 16% of the processing tomato acreage in the Central Valley. Bt was often used in combination with other insecticides, e.g. Lannate or pyrethroid insecticides.

Carbaryl (Sevin) is highly selective for the control of seedling pests such as cutworms. Sevin was applied to 10% of the acreage mostly as a 5% bait formulation. In addition to Sevin for cutworm control, FB and other seedling pest are often controlled with endosulfan (Thiodan) or a pyrethroid application. Thiodan was used on about 5% of the acreage. Overall, the use of insecticides on processing tomatoes is relatively low compared to that on fresh market tomatoes, which face much more demanding quality standards. The average insecticide (material) cost per acre for processing tomatoes in the Central Valley in 1999 was about $17.00.

Fresh Market Tomatoes in the Coastal Region

The coastal region (Alameda, Contra Costa, Del Norte, Humboldt, Lake, Marin, Mendocino, Monterey, Napa, San Benito, San Mateo, Santa Clara, Santa Cruz, Sonoma, Los Angeles, Orange, San Diego, San Luis Obispo, Santa Barbara and Ventura counties) produces about 20% of California's fresh market tomatoes, consisting of mostly pole tomatoes. The majority of coastal production is concentrated in Southern California. Moderate temperatures along the coast allows for year round production. This extended growing period with overlapping crops can contribute to significant insect pest problems particularly with pests that do not diapause (e.g. TPW). This extended growing period with increased pest pressure results in multiple insecticide applications. In addition, a sizable portion of the tomato crop is grown organically which also results in multiple insecticide applications (Table 2).

In 1999 Bt was applied to about 80% of the acreage. Both conventional and organic growers use Bt. Bt is a microbial larvicide that effectively controls hornworms and loopers, but is much less effective against BAW, TFW and TPW unless targeted against newly hatched larvae. However, given the limited options available to organic growers the use of Bt is one of the primary choices for lepidopterous pest control. In addition to Bt organic growers use repeated applications of azadirachtin, clarified neem oil and pyrethrins. The 1999 PUR data indicates that fresh market growers applied these products about four times per acre. Organic growers use these product more heavily than conventional growers. Since conventional growers use considerable amounts of Bt, azadirachtin, clarified neem oil and pyrethrins, it is not possible to totally separate the insecticide cost and use patterns between conventional or organic production from the PUR data. In addition conventional growers applied Success to about 50% of the acreage. Although Success is not an organically approved insecticide it provides selective control of lepidopterous pests, particularly BAW. Success is also effective against thrips and at very high rates for control of leafminers.

In spite of the heavy use of selective materials, broad-spectrum insecticides did play a considerable role for tomato growers along the coastal region. Two pyrethroids, two carbamates, and four OP insecticides made up the bulk of remaining insecticide use. The pyrethroid insecticides, Asana and Baythroid, were applied on 30.8% and 9.3% of the acreage, respectively. These pyrethroid insecticides were most often applied for control of lepidopterous pests, although these products can also work against several other common tomato pests such as thrips, FB and PA. The carbamate insecticide, Lannate, was applied to control lepidopterous pests while oxamyl (Vydate) was applied to control nematodes as well as leafminers and aphids. Vydate is often applied systemically through drip irrigation. Lannate and Vydate were applied to about 50% of the acreage. The OP insecticides Monitor , Dimethoate, azinphos-methyl (Guthion) and diazinon (Diazinon) are all used predominantly for aphid control. However, Dimethoate and Monitor are also used for stink bug control and Diazinon and Guthion are used to control armyworms, leafminers, aphids and seedling pests such as cutworms and wire worms. These four OP insecticides were applied to about 50% of the acreage. The only other insecticide used to any extent was imidacloprid (Provado/Admire). Provado/Admire is applied as a systemic (Admire) or foliar (Provado) treatment for control of aphids and whiteflies. Admire is applied through the drip irrigation system. Provado/Admire can also be applied to control thrips when populations increased to damaging numbers. A benefit of using Provado/Admire is its relative selectively to important parasitic hymenoptera. The average insecticide (material) cost per acre for fresh market tomatoes in the coastal region in 1999 was about $104.00.

Fresh Market Tomatoes in the Central Valley

The Central Valley produces about 75% of California's fresh market tomatoes. Fresh market tomato production in the Central Valley can be divided into northern and southern areas by quantity and cultivar. About 45% of the state's fresh market crop are produced from bush varieties in the northern counties of San Joaquin, Stanislaus and Merced. Planting in this area occurs through the spring with harvests generally completed by November. The Central Valley south of Merced produces a more diverse crop consisting of bush and pole tomatoes, particularly pole cherry tomatoes in the Fresno area. This region produces about 30% of California’s fresh market tomatoes. The southern region of the Central Valley plants from February to March with harvest completed by the end of the summer.

On average more than three insecticide applications per acre were applied to fresh market tomatoes in 1999. The dominant insecticides used in this region were Lannate and Bt (Table 3). Lannate is an effective and inexpensive insecticide that is used to control lepidopterous pests, especially the BAW, TFW and TPW and was applied to 72% of the acreage. However, some populations of BAW in California are known to have developed resistance to Lannate. Lannate is also tank mixed with Asana for stink bug control. Also, Lannate can cause flare-ups of leafminer populations by the suppression of leafminer parasitoids. The other most widely used insecticide was Bt. Bt was used to treat 65% of the fresh market tomato acreage in the Central Valley. Bt is frequently tank mixed with Lannate. Bt is effective against foliage feeding lepidopterous pests such as loopers and hornworms, but will only suppress BAW and TFW populations.

OP insecticides are not widely used on fresh market tomatoes in the Central Valley. The most widely applied OP insecticide on fresh market tomatoes in the Central Valley was Dimethoate which was applied on over 37% of the acres for stink bug and aphid control. The second most widely used OP insecticide was Monitor, which was applied on 17% of the acreage. Monitor was most often used to control aphids and stink bugs.

The pyrethroid insecticides were applied to over half of the acreage with Asana being applied to about a 1/3 of the acreage. Asana is often applied in tank mixtures along with Lannate. This combination can be particularly effective against any of the lepidopterous pests and stink bugs. However, the combination of Asana and Lannate will suppress beneficial insect populations which may lead to secondary outbreaks of leafminer.

Provado or Admire was applied to about 23% of the total fresh market producing acreage in the Central Valley. Provado is applied as a foliar application and Admire is applied as a systemic soil application through the drip line. Since a much higher rate of imidacloprid in the form of Admire must be applied on a per acre basis as compared to Provado, Admire is not used to the extent as Provado. Admire is only used on pole tomatoes as a preventative aphid and whitefly control material.

Success is an effective material for control of lepidopterous pests, but is a high-priced alternative to some of the more widely used products. The advantage of Success is the control of leafminers, while simultaneously preserving their natural enemies. Success was applied on about 13% of the fresh market tomato acreage in the Central Valley. Sevin is used by fresh market tomato growers mainly for control of seedling pests. Sevin provides effective control for seedling pests such as cutworms. Sevin was applied to 11% of the acreage mostly as a 5% bait formulation. In addition to Sevin for cutworm control, FB and other seedling pests are often controlled with Thiodan or a pyrethroid application. Thiodan was used on about 5% of the acreage. The average insecticide (material) cost per acre for processing tomatoes in the Central Valley in 1999 was about $39.00

Fresh Market Tomatoes in the Desert Region

Fresh market tomato production in the desert region is concentrated on 2,000 acres in the Imperial Valley and accounts for 5% of the state's fresh market tomato crop. A majority of the crop is grown as bush tomatoes. Planting occurs from late winter through early spring, with harvest completed by the beginning of the summer. The short growing season gives pest populations less time to build up, however the warmer climate contributes to rapid development. The key insect pests are lepidopterous larval and aphids, particularly PA. The most widely used insecticide in the desert region was Bt, which is often combined with Lannate or a pyrethroid insecticide, e.g. Asana, Warrior and Baythroid, for lepidopterous larval control (Table 4). Bt was applied to about 79% of the acreage while Lannate was applied to about 40% of the acreage. A pyrethroid insecticide was applied over one times per acre. Success was applied to about 30% of the acreage.

Success has a more limited range of efficacy as compared to the pyrethroid insecticides and is more expensive. However, it is very effective, particularly against BAW. Aphids and whiteflies are a major concern in the desert region. Aphids and whiteflies are controlled Provado. Provado was applied to about 25% of the acreage. Due to the high cost of Provado, aphids are also controlled with Monitor that was used on about 8% of the acreage. Thus, very little OP insecticides are used on tomatoes in the lower desert. The only other insecticide used to any extent is Sevin. Sevin applied as a 5% bait formulation is highly selective for the control of seedling pests such as cutworms. Sevin was applied to 7% of the acreage. The average insecticide (material) cost per acre for processing tomatoes in the desert region in 1999 was about $44.00.

OP Free – Pest Management Program with Available Technology

The OP free programs below were constructed with currently registered insecticides for immediate implementation and without regard to resistance management consequences. Eliminating OP insecticides from tomato production would have minor impact with the exception aphid control in fresh market and processing tomatoes in all of the state and stink bug control in processing tomatoes in the Central Valley.

Processing Tomatoes in the Central Valley

The OP insecticides are used primarily for aphid and stink bug control Central Valley. The OP free program would need to replace Dimethoate that was used on about 50% of the acreage and Monitor and Diazinon that was used on an additional 15% of the acreage. Aphid control would rely largely on Provado and Actara with some use of pyrethroid, Warrior. There is some aphid resistant processing tomato varieties that would be grown. However, these varieties can't be universally planted because of processor specifications and aphid biotypes that have overcome the resistance. Provado and Actara provide excellent aphid control. There would be a sharp increase in the use of Provado and Actara. Provado use would increase to about 3/4 of an application per acre in the OP free program (Table 5). The use of Provado and Actara would also indirectly control whiteflies and provide some suppression of lygus. However, Provado and Actara provide very limited stink bug control. Without the availability of Dimethoate and Monitor, stink bug control would rely on the pyrethroid insecticides (Asana, Warrior, Baythroid and Danitol) used alone or in combination with either Lannate or Actara or Provado. It is expected that the use of pyrethroid insecticides would increase dramatically with the elimination of OP insecticides. The pyrethroid insecticides would be applied to about 3/4 of the acreage while Lannate would be applied to about a 1/4 of the acreage. The pyrethroid insecticides would also be used to control lepidopterous pests along with Lannate. Lannate would be combined with Bt for lepidopterous control. The use of Success, Confirm and Avaunt would be expected to increase but only marginally because of cost as compared to the pyrethroid insecticides and Lannate. The use of these reduced risk insecticides would be expected to increase over time as their price falls and they become more cost competitive with the pyrethroid insecticides. These reduced risk insecticides would be excellent replacements for Lannate and the pyrethroid insecticides because of the low impact on beneficial insects and mites. Control of seedling pests (FB and CW) would rely on Sevin, Thiodan and to some extent on pyrethroid insecticides. These insecticides would be applied to about 15% of the acreage. Sevin bait would be used for CW control while Thiodan and pyrethroid insecticides used for FB control. There are restrictions on where Thiodan can be applied because of surface water contamination concerns.

Fresh Market Tomatoes in the Coastal Region

Fresh market tomatoes in the Coastal Region are largely pole tomatoes with a much different input structure than fresh market bush tomatoes. Pole tomatoes are harvested weekly from early spring through fall and the crop must be protected for an extended period of time. Most pole tomatoes are produced using conventional insecticides with only a few hundred acres of organic pole tomatoes.

Organic growers would not be affected by the OP free program and would continue to rely on repeated applications of azadirachtin, pyrethrins and Bt. Azadirachtin and pyrethrins are not used to a great extent by conventional growers. However, the total number of applications on all acreage of these insecticides would be low because only a few hundred acres of organic tomatoes are grown along the coast. Bt would be applied about one time, azadirachtin would be applied about two times and pyrethrins would be applied to about 50% of the acreage (Table 6). Both conventional and organic growers use Bt. Conventional growers would combine Bt with Lannate while organic growers would combine Bt with azadirachtin or pyrethrins. Organic growers would applied azadirachtin, pyrethrins and Bt alone or combination about 1 to 2 times per week throughout the season.

The OP insecticides are used primarily for aphid control. The OP free program would need to replace Monitor that was used on about 25% of the acreage and Dimethoate and Diazinon that was used on an additional 24% of the acreage. Provado and Actara or Admire and Platinum would replace these insecticides. These insecticides provide excellent aphid control and there would be a sharp increase in their use despite increased costs. Provado or Actara use would increase to about two times while Admire or Platinum would be applied once. Admire and Platinum are systemic insecticides and would be applied through the drip irrigation system.

Control of lepidopterous pests would rely on pyrethroid insecticides, Lannate and Bt combination and Success, Confirm or Avaunt. Pyrethroid insecticides would be used on about 1/2 the acreage. Beside lepidopterous pests, the pyrethroid insecticides would also be used for a number of pests such as plant bugs, FB, whiteflies, etc. Lannate combined with Bt would be applied to about a 1/3 of the acreage. This combination is effective against a wide spectrum of lepidopterous pests. However, Lannate is very disruptive to the parasitoids of VL and SL. VL and SL populations often explode late in the season following Lannate applications. Large populations of VL or SL would require the application of Vydate. Vydate would be applied through the drip irrigation system to about 1/4 of the acreage. Vydate is also an effective nematicide. The use of Success, Confirm and Avaunt would be expected to increase to a greater extent in Coastal fresh market tomatoes as compared to Central Valley processing tomatoes. The fresh market tomatoes can afford the higher priced reduced risk insecticides because of the overall higher productivity of Coastal fresh market tomatoes. The use of these reduced risk insecticides would be expected to increase even further over time as their price falls and they become more cost competitive with the pyrethroid insecticides. These reduced risk insecticides would be excellent replacements for Lannate and the pyrethroid insecticides because of the low impact on beneficial insects and mites.

Fresh Market Tomatoes in the Central Valley

Since fresh market tomatoes in the Central Valley do not rely heavily on OP insecticides except for control of stink bug and aphids, the OP free program would be similar to the current pest management program. Also the OP free program in fresh market tomatoes would be similar to the program in processing tomatoes. OP insecticides are used primarily for aphid and stink bug control. The OP free program would need to replace Dimethoate that was used on about 38% of the acreage and Monitor and Diazinon that was used on an additional 18% of the acreage. Aphid control would rely largely on Provado and Actara that provide excellent aphid control. There would be a sharp increase in the use of Provado and Actara. Provado and Actara use would increase to about 3/4 of an application per acre in the OP free program (Table 7). The use of Provado and Actara would also indirectly control whiteflies and provide some suppression of lygus. However, Provado and Actara provide very limited stink bug control. Without the availability of Dimethoate and Monitor, stink bug control would rely on the pyrethroid insecticides (particularly Warrior) used alone or in combination with either Lannate, Provado or Actara. It is expected that the use of pyrethroid insecticides would increase dramatically with the elimination of OP insecticides. The pyrethroid insecticides would be applied to about 1/2 of the acreage while Lannate would be applied to about a 3/4 of the acreage. The pyrethroid insecticides would also be used to control lepidopterous pests along with Lannate. Lannate would be combined with Bt for lepidopteran control. The use of Success, Confirm and Avaunt would be expected to increase but only marginally because of cost as compared to the pyrethroid insecticides and Lannate. The use of these reduced risk insecticides would be expected to increase over time as their price falls and they become more cost competitive with the pyrethroid insecticides. These reduced risk insecticides would be excellent replacements for Lannate and the pyrethroid insecticides for lepidopteran control because of the low impact on beneficial insects. Because of the disruptive effects on Lannate and the pyrethroid insecticides, Agri-Mek, Trigard or Vydate would be applied to about 10% of the acreage. Control of seedling pests (FB and CW) would rely on Sevin, Thiodan and to some extent on pyrethroid insecticides. These insecticides would be applied to about 10% of the acreage. Sevin bait would be used for CW control while Thiodan and pyrethroid insecticides would be used for FB control.

Fresh Market Tomatoes in the Desert Region

The OP free program would be very similar to the current pest management program since OP insecticides are not used to any extent in the Desert Region. In 1999, only 8% of the acreage was treated with an OP insecticide. The key insect pests are lepidopterous larval and aphids, particularly PA. Aphids and whiteflies would be controlled Provado or Actara. Provado or Actara would be applied to about 1/3 of the acreage (Table 8). Lepidopterous larval control would rely on a pyrethroid insecticide, e.g. Asana, Warrior and Baythroid or Lannate combined with Bt. A pyrethroid insecticide would be applied about one and half times while Lannate would be applied to about a 1/3 of the acreage. Bt would be applied to about 3/4 of the acreage and would be combined with Lannate or pyrethroid insecticide. The use of Success, Confirm and Avaunt would be expected to increase above current use but only marginally because of cost.

The use of these reduced risk insecticides would be expected to increase over time as their price falls and they become more cost competitive with the pyrethroid insecticides. It is projected that about 1/3 of the acreage would be treated with a reduced risk insecticide. Control of seedling pests (FB and CW) would rely on Sevin and pyrethroid insecticides. These insecticides would be applied to about 5% of the acreage. Sevin bait would be used for CW control while pyrethroid insecticides would be used for FB control.

OP Free – Pest Management Program with Emerging Technology

The IPM program below was constructed with currently registered insecticides and/or insecticides that are anticipated to be registered within four to five years and technologies. The IPM program would require a greater reliance on cultural and biological alternatives and a partnership of processors and growers that would offer more flexibility of variety selection and specifying processing use for which the tomatoes are intended. The IPM program with emerging technology would produce a stable long-term program that would allow for much greater impact of beneficial insects and mites on the pest populations. The number of applications as well as the selection of material will depend on the growing area and pest pressure.

Processing Tomatoes in the Central Valley

The OP free program with emerging technology would rely on Provado and Actara plus resistant varieties for aphid control, Success, Intrepid, Avaunt, emamectin benzoate (Proclaim) and Bt for lepidopterous larval control, neonicotinoid plus pyrethroid insecticides timed to a phenology model for stink bug control with better specifications of the intended processing use of the tomatoes and Sevin and Thiodan for seedling pests (Table 9). The use of Provado and Actara would remain the same in the OP free program with emerging technology as in the OP free program with available technology at about 3/4 of an application per acre. However, the amount of Provado and Actara might be reduced with increased use of aphid tolerant tomato varieties. The use of Provado and Actara would also indirectly control whiteflies and provide some suppression of lygus. However, Provado and Actara alone provide very limited stink bug control. Stink bug control would rely on the pyrethroid insecticides (especially Warrior) in combination with Provado or Actara. Ground applications that provide improved coverage would replace air applications. There is no reduced risk insecticide currently under development that effectively controls stinks bugs. The pyrethroid insecticides would be disruptive to the beneficial insect and mite complex but pyrethroid insecticides would be applied to only about 10% of the acreage. Their disruptive effect would hopefully be limited. The pyrethroid insecticides use would be limited to stink bug control and would not be used for lepidopterous larval control. Lepidopterous larvae would be controlled with one of the reduced risk insecticides, which are Success, Intrepid, Avaunt, Proclaim and Bt. Success, Intrepid, Avaunt and Proclaim would be applied about two times while Bt would be applied once. This increased use of the reduced risk insecticide is the result of the elimination of Lannate and the reduction of the pyrethroid insecticide in the OP free program with available technology. Pyrethroid insecticides would not be used for seedling pests. Control of seedling pests (FB and CW) would rely on Sevin bait and Thiodan. These insecticides would be applied to about 15% of the acreage. The amount of insecticides could be reduced by using transplants in areas known to be at high risk for injury by seedling pests. Sevin bait would be used for CW control while Thiodan and pyrethroid insecticides used for FB control.

Fresh Market Tomatoes in the Coastal Region

OP free program with emerging technology would not affect organic growers. Organic growers would rely on repeated applications of azadirachtin, pyrethrins and Bt. However, conventional growers would rely on repeated applications of reduced risk insecticides such as Success, Intrepid, Avaunt, Proclaim and Bt for lepidopterous larval control and neonicotinoid insecticides, Provado, Admire, Actara or Platinum for aphid and whitefly control (Table 10). These insecticides have a low impact on beneficial insects and mites. Secondary pests such as leafminers should not be a significant problem.

Control of lepidopterous pests would rely on two applications of Success, Intrepid, Avaunt and Proclaim and one application of Bt. Since these insecticides are selective and are not disruptive of the parasitoids of VL and SL, only about 5% of the acreage would require an application of Agri-Mek or Trigard for leafminer and whitefly control. Control of aphids would rely on one application of Admire or Platinum applied through the drip irrigation system or two applications of Provado or Actara. Provado and Actara are foliar applied insecticides and applications can be timed for the appearance of the aphids while Admire and Platinum are systemic insecticides and would be applied through the drip irrigation system as preventative insecticides. Provado and/or Actara would be applied twice per season as the aphid populations began to increase. Admire or Platinum would be applied once shortly after transplanting. If Admire or Platinum is applied, then Provado or Actara would not be necessary except under extremely high aphid pressure. Besides aphid control, the neonicotinoid insecticides will also suppress whiteflies.

Fresh Market Tomatoes in the Central Valley

The OP free program with emerging technology in fresh market tomatoes would be similar to the OP free program with emerging technology in processing tomatoes. The OP free program would rely on Provado and Actara for aphid control, Success, Intrepid, Avaunt, Proclaim and Bt for lepidopterous larval control, neonicotinoid and pyrethroid insecticides combinations for stink bug control and Sevin and Thiodan for seedling pests (Table 11). Provado and Actara would be applied once per acre in the OP free program with emerging technology as compared to 3/4 of an application in the OP free program with available technology. The use of Provado and Actara would also indirectly control whiteflies and provide some suppression of lygus. However, Provado and Actara alone provide very limited stink bug control. Stink bug control would rely on neonicotinoids in combination with pyrethroid insecticides. There is no reduced risk insecticide currently under development that effectively controls stink bugs. The pyrethroid insecticides would be disruptive to the beneficial insect complex but pyrethroid insecticides would be applied to only about 10% of the acreage and limited to stink bug control. The pyrethroid insecticides would not be used for lepidopterous larval control. Lepidopterous larvae would be controlled with one of the reduced risk insecticides, which are Success, Intrepid, Avaunt, Proclaim and Bt. Success, Intrepid, Avaunt and Proclaim would be applied about 1 and 1/2 times. However Bt would be applied to about 2/3 of the acreage. This increased use of the reduced risk insecticide is the result of the elimination of Lannate and the reduction of the pyrethroid insecticide in the OP free program with available technology. Control of seedling pests (FB and CW) would rely on Sevin and Thiodan. These insecticides would be applied to about 15% of the acreage. The amount of insecticides could be reduced by using transplants in areas known to be at high risk for injury by seedling pests. Sevin bait would be used for CW control while Thiodan would be used for FB control.

Fresh Market Tomatoes in the Desert Region

The OP free program would rely on Provado and Actara for aphid control, Success, Intrepid, Avaunt and Proclaim and Bt for lepidopterous larval control, pyrethroid insecticides for stink bug control and Sevin and Thiodan for seedling pests (Table 12). The key insect pests are lepidopterous larvae and aphids, particularly PA. Aphids would be controlled by Provado or Actara. Provado or Actara would be applied to about 1/2 of the acreage. The use of Provado and Actara would also indirectly control whiteflies and provide some suppression of lygus. Stink bugs are not a significant pest of tomatoes in the desert region. Control of lepidopterous pests would rely on about two and half applications of Success, Intrepid, Avaunt or Proclaim and one application of Bt. The use of Success, Intrepid, Avaunt, Proclaim and Bt would eliminate the use of pyrethroid insecticides. This would allow for greater beneficial insect and mite activity against aphids and whiteflies. Pyrethroid insecticides would not be used for seedling pests. Control of seedling pests (FB and CW) would rely on Sevin and Thiodan. These insecticides would be applied to about 15% of the acreage. Sevin bait would be used for CW control while Thiodan would be used for FB control.

Addendum

Two new insecticides, acetamiprid (Assail) and pymetrozine (Fulfill), have been registered in tomatoes since the economic analysis. Assail has aphid/whitefly activity as well as some lepidopteran larval activity. Assail will be useful when multiple pests, i.e., aphid/whitefly and lepidopteran pests, are present simultaneously. Assail may have a significant impact on tomato production and may be a replacement for acephate (Orthene). However, Assail is not as efficacious for lepidopteran larval control as Orthene. Other reduced risk insecticides may need to be combined with Assail to achieve a high level of lepidopteran larval control. Fulfill targets aphid/whiteflies. However, Fulfill is weaker in aphids/whitefly control than the neonicotinoid insecticides, i.e., Assail, Provado/Admire and Actara/Platinum. Fulfill will provide only minor competition to neonicotinoid insecticides for market share. Competition to the neonicotinoid grouping in aphid control will come from *Lambda*-cyhalothrin (Warrior). Hopefully, this competition will reduce costs for the neonicotinoid insecticides.

Table 1. Insecticide and Miticide Use on Processing Tomatoes in the Central Valley of CA, 1999

Material*	**Lb (ai)**	**Acres Treated**	**% Acres Treated**	**Costs**
Bacillus thuringiensis (Various Products)	4,638	50,135	15.7	$143,219
carbaryl (Sevin)	26,796	31,986	10	$186,499
diazinon (Diazinon)	13,577	26,223	8.2	$125,450
dimethoate (Dimethoate)	79,532	173,634	54.5	$783,386
endosulfan (Thiodan, Phaser)	21,174	23,085	7.2	$247,734
esfenvalerate (Asana)	3,259	80,348	25.2	$592,539
imidacloprid (Admire, Provado)	398	8,864	2.8	$135,551
lambda-Cyhalothrin (Warrior)	2,272	84,367	26.5	$954,051
methamidophos (Monitor)	18,546	22,661	7.1	$438,231
methomyl (Lannate)	50,802	80,070	25.1	$1,128,817
oxamyl (Vydate)	2,510	3,584	1.1	$80,310
permethrin (Pounce, Ambush)	3,868	23,231	7.3	$261,101
spinosad (Success)	1,335	14,719	4.6	$427,283

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre planted for the Central Valley is about $17.29.

Table 2. Insecticide and Miticide Use on Tomatoes (fresh) in the Coastal Regions of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
avermectin (Agri-Mek)	6	348	2.8	$28,295
azadirachtin (various products)	181	24,210	192.4	$213,373
azinphos-methyl (Guthion)	874	1,163	9.2	$18,172
Bacillus thuringiensis (Various Products)	1,206	10,093	80.2	$37,251
carbaryl (Sevin)	65	66	0.5	$451
clarified neem oil (various products)	46,552	18,007	143.1	$93,104
cyfluthrin (Baythroid)	51	1,164	9.3	$14,793
diazinon (Diazinon)	369	698	5.6	$3,411
dimethoate (Dimethoate)	1,097	2,282	18.1	$10,805
endosulfan (Thiodan, Phaser)	72	82	0.7	$848
esfenvalerate (Asana)	169	3,869	30.8	$30,728
imidacloprid (Admire, Provado)	649	3,527	28	$220,985
lambda-Cyhalothrin (Warrior)	1	27	0.2	$328
methamidophos (Monitor)	2,192	3,108	24.7	$51,807
methomyl (Lannate)	3,401	4,215	33.5	$75,563
oxamyl (Vydate)	1,828	2,599	20.7	$58,502
permethrin (Pounce)	72	52	0.4	$4,848
pyrethrins (various products)	181	7,775	61.8	$289,936
spinosad (Success)	479	5,822	46.3	$153,146

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre planted for the Coastal Regions is about $103.82.

Table 3. Insecticide and Miticide Use on Tomatoes (fresh) in the Central Valley of CA, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
avermectin (Agri-Mek)	22	2,453	4.9	$112,680
azadirachtin (various products)	1	43	0.1	$1,247
azinphos-methyl (Guthion)	1	1	< 0.1	$16
Bacillus thuringiensis (Various Products)	3,496	24,897	49.7	$107,965
carbaryl (Sevin)	3,853	5,618	11.2	$26,814
clarified neem oil (various products)	69	41	0.1	$138
cyfluthrin (Baythroid)	56	1,307	2.6	$16,312
diazinon (Diazinon)	360	634	1.3	$3,326
dimethoate (Dimethoate)	7,883	18,820	37.6	$77,644
endosulfan (Thiodan, Phaser)	1,906	2,436	4.9	$22,306
esfenvalerate (Asana)	692	16,424	32.8	$125,758
imidacloprid (Admire, Provado)	1,072	11,399	22.8	$364,848
lambda-Cyhalothrin (Warrior)	98	3,424	6.8	$41,320
methamidophos (Monitor)	6,814	8,513	17	$161,023
methomyl (Lannate)	24,032	36,111	72.1	$533,981
oxamyl (Vydate)	2,266	3,423	6.8	$72,497
permethrin (Pounce)	1,390	7,470	14.9	$93,826
spinosad (Success)	570	6,353	12.7	$182,416

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre planted for the Central Valley is about $ 38.84.

Table 4. Insecticide and Miticide Use on Tomatoes (fresh) in the Desert Regions of CA, 1999

Material*	**Lb (ai)**	**Acres Treated**	**% Acres Treated**	**Costs**
avermectin (Agri-Mek)	< 1	4	0.2	$150
Bacillus thuringiensis (Various Products)	156	1,520	68.3	$4,821
carbaryl (Sevin)	210	150	6.7	$1,462
clarified neem oil (Trilogy)	10	10	0.5	$19
cyfluthrin (Baythroid)	25	622	27.9	$7,238
esfenvalerate (Asana)	41	1,033	46.4	$7,404
imidacloprid (Admire, Provado)	86	585	26.3	$29,257
lambda-Cyhalothrin (Warrior)	22	908	40.8	$9,156
methamidophos (Monitor)	60	176	7.9	$1,421
methomyl (Lannate)	798	875	39.3	$17,741
permethrin (Pounce)	4	20	0.9	$270
spinosad (Success)	56	652	29.3	$17,824

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre planted for the Desert Regions is about $ 43.50.

Table 5. Insecticide Use in an OP Free Pest Management Program with Available Technology on Tomatoes (processed) in the Central Valley of California

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
Carbaryl				
(Sevin 80S)	1 lb	1/10	Flea beetle &	
(Sevin 5% bait)	30 lb		cutworm	
endosulfan	2 lb	1/20	FB, springtails &	
(Thiodan 50W)			garden symphylans	
esfenvalerate	1/2 pt	3/4	Lep. larvae,	Disrupts bio-control
(Asana XL)			stink & lygus bug	
or				
lambda-cyhalothrin	3/16 pt		Lep. larvae,	Disrupts bio-control
(Warrior T)			stink & lygus bug	
or				
cyfluthrin	1/8 pt		Lep. larvae,	Disrupts bio-control
(Baythroid 2)			stink & lygus bug	
or				
fenpropathrin	5/8 pt		Lep. larvae,	Disrupts bio-control
(Danitol 2.4 EC)			stink & lygus bug	
spinosad	3/8 pt	1/10	Lep. larvae &	
(Success 2SC)			leafminer	
or				
tebufenozide	1 pt		Lep. larvae	
(Confirm 2F)				
or				
indoxacarb	1/5 lb		Lep. larvae	
(Avaunt 30 WDG)				
methomyl	1 lb	1/4	Lep. larvae	Disrupts bio-control
(Lannate SP)			& aphids	
Bacillus thuringiensis	1 lb	1/4	Lep. larvae	
(Dipel 2X, others)				
imidacloprid	1/4 pt	3/4	Aphids &	
(Provado 1.6F)			whiteflies	
or				
thiamethoxam	1/4 lb			
(Actara 25WG)				

Table 6. Insecticide Use in an OP Free Pest Management Program with Available Technology on Tomatoes (fresh) in the Coastal Region of CA

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
esfenvalerate (Asana XL)	1/2 pt	1/2	Lep. larvae	Disrupts bio-control
or				
lambda-cyhalothrin (Warrior T)	3/16 pt		Lep. larvae	Disrupts bio-control
or				
cyfluthrin (Baythroid 2)	1/8 pt		Lep. larvae	Disrupts bio-control
or				
fenpropathrin (Danitol 2.4 EC)	5/8 pt		Lep. larvae	Disrupts bio-control
spinosad (Success 2SC)	3/8 pt	1	Lep. larvae Leafminer	
or				
tebufenozide (Confirm 2F)	1 pt		Lep. larvae	
or				
indoxacarb (Avaunt 30 WDG)	1/5 lb		Lep. Larvae	
methomyl (Lannate SP)	1 lb	1/3	Lep. larvae & aphids	Disrupts bio-control
oxamyl (Vydate L)	3 pt	1/4	Leafminers, aphids & nematodes	SL resistant
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1	Lep. larvae	Used by conventional & organic growers
azadirachtin (various products)	3/8 pt	2	Aphids, lep. larvae whiteflies & others	Used largely by organic growers
pyrethrins (various products)	3/4 pt	1/2	Aphids, lep. larvae & others	Used largely by organic growers
imidacloprid (Provado 1.6F	1/4 pt	2	Aphids & whiteflies	
or				
(Admire 2F)	1pt	1		
or				
thiamethoxam (Actara 25WG)	1/4 lb	2		
or				
(Platinum 2SC)	1/2 pt	1		

Table 7. Insecticide Use in an OP Free Pest Management Program with Available Technology on Tomatoes (fresh) in the Central Valley of California

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
Carbaryl				
(Sevin 80S)	1 lb	1/10	Flea beetle &	
(Sevin 5% bait)	30 lb		cutworm	
endosulfan	2 lb	1/20	FB, springtails &	
(Thiodan 50W)			garden symphylans	
esfenvalerate	1/2 pt	3/4	Lep. larvae	Disrupts bio-control
(Asana XL)				
or				
lambda-cyhalothrin	3/16 pt		Lep. larvae,	Disrupts bio-control
(Warrior T)			stink & lygus bug	
or				
cyfluthrin	1/8 pt		Lep. larvae,	Disrupts bio-control
(Baythroid 2)			stink & lygus bug	
or				
fenpropathrin	5/8 pt		Lep. larvae,	Disrupts bio-control
(Danitol 2.4 EC)			stink & lygus bug	
spinosad	3/8 pt	1/10	Lep. larvae &	
(Success 2SC)			Leafminer	
or				
tebufenozide			Lep. Larvae	
(Confirm 2F)	1 pt			
or				
indoxacarb			Lep. Larvae	
(Avaunt 30 WDG)	1/5 lb			
methomyl	1 lb	3/4	Lep. larvae	Disrupts bio-control
(Lannate SP)			& aphids	
abamectin	1/2 pt	1/20	Leafminers &	
(Agri-mek 0.15EC)			whiteflies	
or				
cryomazine	1/6 lb		Leafminers	
Trigard 75WP				
oxamyl	3 pt	1/20	Leafminers, aphids	SL resistant
(Vydate L)			& nematodes	
Bacillus thuringiensis	1 lb	2/3	Lep. larvae	
(Dipel 2X, others)				
imidacloprid	1/4 pt	3/4	Aphids &	
(Provado 1.6F)			whiteflies	
or				
thiamethoxam	1/4 lb			
(Actara 25WG)				

Table 8. Insecticide Use in an OP Free Pest Management Program with Available Technology on Tomatoes (fresh) in the Desert Region of California

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
Carbaryl				
(Sevin 80S)	1 lb	1/20	Flea beetle &	
(Sevin 5% bait)	30 lb		cutworm	
esfenvalerate	1/2 pt	1 1/2	Lep. larvae,	Disrupts bio-control
(Asana XL)			lygus bug	
or				
lambda-cyhalothrin	3/16 pt		Lep. larvae,	Disrupts bio-control
(Warrior T)			lygus bug	
or				
cyfluthrin	1/8 pt		Lep. larvae,	Disrupts bio-control
(Baythroid 2)			lygus bug	
or				
fenpropathrin	5/8 pt		Lep. larvae,	Disrupts bio-control
(Danitol 2.4 EC)			lygus bug	
spinosad	3/8 pt	1/3	Lep. larvae &	
(Success 2SC)			leafminer	
or				
tebufenozide			Lep. larvae	
(Confirm 2F)	1 pt			
or				
indoxacarb			Lep. larvae	
(Avaunt 30 WDG)	1/5 lb			
methomyl	1 lb	1/3	Lep. larvae	Disrupts bio-control
(Lannate SP)			& aphids	
Bacillus thuringiensis	1 lb	3/4	Lep. larvae	
(Dipel 2X, others)				
imidacloprid	1/4 pt	1/3	Aphids &	
(Provado 1.6F)			whiteflies	
or				
thiamethoxam	1/4 lb			
(Actara 25WG)				

Table 9. Insecticide Use in an OP Free Pest Management Program with Emerging Technology on Tomatoes (processed) in the Central Valley Region of California

Material	**Rate Form./ac**	**# Appl./ Season.**	**Pest**	**Notes**
Carbaryl				
(Sevin 80S)	1 lb	1/10	FB & cutworm	
(Sevin 5% bait)	30 lb			
endosulfan (Thiodan 50W)	2 lb	1/20	FB, springtails & garden symphylans	
esfenvalerate (Asana XL)	1/2 pt	1/10	Stink bug	Disrupts bio-control
or				
lambda-cyhalothrin (Warrior T)	3/16 pt		Stink bug	Disrupts bio-control
or				
cyfluthrin (Baythroid 2)	1/8 pt		Stink bug	Disrupts bio-control
or				
fenpropathrin (Danitol 2.4 EC)	5/8 pt		Stink bug	Disrupts bio-control
spinosad (Success 2SC)	3/8 pt	2	Lep. larvae & Leafminer	
or				
methoxyfenozide (Intrepid 2F)	1/2 pt		Lep. larvae	Not registered
or				
indoxacarb (Avaunt 30 WDG)	1/5 lb		Lep. larvae	
or				
emamectin benzoate (Proclaim 5WDG)	1/4 lb			Not registered
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1	Lep. larvae	
imidacloprid (Provado 1.6F)	1/4 pt	3/4	Aphids & whiteflies	
or				
thiamethoxam (Actara 25WG)	1/4 lb			

Table 10. Insecticide Use in an OP Free Pest Management Program with Emerging Technology on Tomatoes (fresh) in the Coastal Region of California

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
spinosad (Success 2SC)	1/2 pt	2	Lep. larvae	
or				
methoxyfenozide (Intrepid 2F)	1/2 pt			Not registered
or				
indoxacarb (Avaunt 30 WDG)	1/4 lb			Not registered
or				
emamectin benzoate (Proclaim 5WDG)	1/4 pt			Not registered
Bacillus thuringiensis (Dipel 2X, others)	1 lb	1	Lep. larvae	
abamectin (Agri-mek 0.15EC)	1/2 pt	1/20	Leafminers, whiteflies	
or				
cryomazine Trigard 75WP	1/6 lb		Leafminers	
imidacloprid (Provado 1.6F	1/4 pt	2	Aphids & whiteflies	
or				
(Admire 2F)	1pt	1		
or				
thiamethoxam (Actara 25WG)	1/4 lb	2		
or				
(Platinum 2SC)	1/2 pt	1		

Table 11. Insecticide Use in an OP Free Pest Management Program with Emerging Technology on Tomatoes (fresh) in the Central Valley of California

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
Carbaryl				
(Sevin 80S)	1 lb	1/10	FB and cutworm	
(Sevin 5% bait)	30 lb			
endosulfan (Thiodan 50W)	2 lb	1/20	FB, Springtails and garden symphylans	
esfenvalerate (Asana XL)	1/2 pt	1/10	Stink & lygus bug	Disrupts bio-control
or				
lambda-cyhalothrin (Warrior T)	3/16 pt		Stink & lygus bug	Disrupts bio-control
or				
cyfluthrin (Baythroid 2)	1/8 pt		Stink & lygus bug	Disrupts bio-control
or				
fenpropathrin (Danitol 2.4 EC)	5/8 pt		Stink & lygus bug	Disrupts bio-control
spinosad (Success 2SC)	3/8 pt	1 1/2	Lep. larvae Leafminer	
or				
methoxyfenozide (Intrepid 2F)	1/2 pt		Lep. larvae	Not registered
or				
indoxacarb (Avaunt 30 WDG	1/5 lb		Lep. larvae	
or				
emamectin benzoate (Proclaim 5WDG)	1/4 lb		Lep. larvae	Not registered
Bacillus thuringiensis (Dipel 2X, others)	1 lb	2/3	Lep. larvae	
imidacloprid (Provado 1.6F	1/4 pt	1	Aphids & whiteflies	
or				
thiamethoxam (Actara 25WG)	1/4 lb	1		

Table 12. Insecticide Use in an OP Free Pest Management Program with Emerging Technology on Tomatoes (fresh) in the Desert Region of California

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
Carbaryl				
(Sevin 80S)	1 lb	1/20	Flea beetle &	
(Sevin 5% bait)	30 lb		cutworm	
spinosad	3/8 pt	1 1/2	Lep. larvae	
(Success 2SC)			leafminer	
or				
methoxyfenozide	1/2 pt		Lep. Larvae	Not registered
(Intrepid 2F)				
or				
indoxacarb	1/5 lb		Lep. Larvae	
(Avaunt 30 WDG)				
or				
emamectin benzoate	1/4 lb		Lep. larvae	Not registered
(Proclaim 5WDG)				
Bacillus thuringiensis	1 lb	1	Lep. larvae	
(Dipel 2X, others)				
imidacloprid	1/4 pt	1/2	Aphids &	
(Provado 1.6F)			whiteflies	
or				
thiamethoxam	1/4 lb			
(Actara 25WG)				

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% is produced in the coast region.

The major pests of walnuts are codling moth, navel orangeworm and walnut husk fly. If uncontrolled, these pests may cause economic damage to susceptible cultivars to some degree every year. Insecticide treatments directed against them may induce population increases of a number of occasional pests when beneficial insects are eliminated. Occasional pests of walnuts are walnut aphid, dusky-veined aphid, twospotted spider mite, Pacific spider mite, European red mite, walnut scale, San Jose scale and frosted scale. These pests may cause some economic damage in various growing areas at sporadic intervals.

The San Joaquin and Sacramento valleys are hot, dry interior valleys of the state while the coast region is cool with higher humidity. Climate differences influence pest problems and crop management options. The hot interior valleys have more codling moth and navel orangeworm problems with the associated spider mite, scale and aphid flare-ups than the coast region while the coast region have more walnut husk fly problems than the interior valleys. In addition, insect pest control may vary greatly according to the walnut cultivar. Mid to late maturing cultivars, such as Hartley and Franquette, are less susceptible to codling moth and navel orangeworm damage than are early maturing cultivars, such as Payne or Ashley. However, mid to late maturing cultivars are more susceptible to walnut husk fly damage than early maturing cultivars.

Codling Moth (CM), *Cydia pomonella*

Codling moth is the major insect pest of walnuts and will cause significant damage to early and mid maturing cultivars. The damage caused by this pest differs with each generation. First generation larvae reduce yield directly by causing nuts to drop from the tree. Nuts attacked by the second and third generations remain on the trees but are unmarketable because of the damage to the kernel. CM damaged nuts also serve as a breeding site for Navel orangeworm.

Control of CM has relied on repeated applications of organophosphate (OP) or pyrethroid insecticides. The OP insecticides used to control CM are methyl parathion (Penncap-M), chlorpyrifos (Lorsban), azinphos-methyl (Guthion or Azinphos-M), methidathion (Supracide) and phosmet (Imidan). Supracide and Guithion are extremely harmful to beneficial insects and mites, which control aphids and spider mites. The pyrethroid insecticides used to control CM are permethrin (Pounce) and esfenvalerate (Asana). These insecticides are also very destructive to beneficial insects and mites, which control plant feeding mites and scales. Growers typically apply two to four insecticide applications per year to control CM on early maturing cultivars while zero to two applications per year are required for mid to late maturing cultivars. The insecticides currently used for control of CM are OP and pyrethroid insecticides with a small number of acres treated with insect growth regulator (IGR) insecticides. The OP and pyrethroid insecticides are efficacious and cost effective.

Control of CM has relied more recently on IGR insecticides. The IGR insecticides used to control CM are tebufenozide (Confirm) and diflubenzuron (Dimilin). The IGR insecticides are alternatives to OP and pyrethroid insecticides and are effective against low to moderate CM populations. Recently pyriproxyfen (Esteem), a new IGR insecticide, was registered for use on walnuts. Esteem provides some control of CM but is an excellent scale insecticide. Esteem would be used in situations where walnut or San Jose scale is a problem.

Pheromone mating disruption is not an economically feasible alternative at this time in walnuts because of the large tree size. The large tree size makes placement of the pheromone dispensers difficult and expensive. In addition, a greater amount of pheromone is needed in walnuts orchards compared to apple or pears orchards because of the increase air volume. Pheromone disruption is most effective against a low CM population on small to medium size trees and should be used in combination with other control techniques such as IGR or conventional insecticides. Recent advances in pheromone dispensers (aerosol puffers and micro-encapsulation sprayable formulations) may make pheromonal control more economical in the near future.

Numerous biological control organisms have been reported to attack CM. None are capable of keeping CM populations below the economic damaging levels. A number of exotic parasites have been imported and established in California. However, OP, carbamate and pyrethroid insecticides are highly toxic to these parasites and thus prevent them from being widely established in walnut orchards throughout the state. The mass release of *Trichogramma platneri* has shown some promise in control of CM. For *T. platneri* to be effective, it must be used in combination with another compatible control method, e.g. CM pheromonal control or IGR insecticide. *Bacillus thuringiensis* (Bt) has been extensively evaluated for CM control in walnuts, pears and apples and has not provided control.

In addition, removal of Penncap-M and Lorsban by EPA action would reduce the grower’s ability to manage CM resistance. Penncap-M and Lorsban exhibit negatively correlated cross-resistance to Guthion, Imidan, Asana, Confirm and Dimilin resistant CM. Without Penncap-M and Lorsban, the IGR and pyrethroid resistance in CM would increase over time. At present, moderate CM resistance is found in the southern San Joaquin Valley and northern Sacramento Valley while the rest of the state shows low but significant level of resistance.

Navel Orangeworm (NOW), *Amyelois transitella*

Navel orangeworm is a serious pest of walnuts. However, NOW can only infest sound walnuts after husk split. When the husks of sound nuts begin to split preceding harvest, NOW larvae will enter the nuts and feed on the nutmeat. The larvae overwinter in unharvested nuts from the previous year’s crop, either in trees or on the ground. Adults emerge from the overwintering nuts and lay eggs on CM infested, blighted or sunburned walnuts. This feeding produces webbing and frass, making the product unmarketable. NOW has two or three generations per year.

NOW control is provided by: 1) winter sanitation, 2) CM walnut blight and sunburn control, 3) prompt harvest and 4) husk split insecticide applications. Winter sanitation is the removal and destruction of unharvested walnuts during the winter by shaking the trees and mowing the removed nuts. Good CM, walnut blight and sunburn control will prevent husk damage and subsequent NOW infestation. Prompt harvest after husk split will limit infestation since the longer the time between husk split and harvest, the greater the potential for NOW damage. Husk split insecticide applications are only marginally effective and provide only 50 to 75% control. OP insecticides used for NOW control at husk split are Guthion, Imidan and Supracide. Non-OP alternatives are Pounce and Asana. There are a number of parasites (*Pentalitomastix plethorica* and *Goniozus legneri*) that attack NOW and can reduce the NOW population. However, these parasites are very susceptible to the OP, pyrethroid and carbamate insecticides used to control CM and NOW.

Pheromone mating disruption of NOW is not an economically feasible alternative at this time. NOW mating disruption not only faces the same problem of large tree size as CM mating disruption but also NOW pheromone is chemically unstable. NOW pheromone is readily oxidized and has a very short half-life once exposed to air. However, NOW pheromone contained within cans in the aerosol puffers are not exposed to air. The use of aerosol puffers may make pheromonal control of NOW feasible in the future. Research is underway to investigate the methodology of using aerosol puffers for NOW control.

Walnut Husk Fly (WHF), *Rhagoletis completa*

Walnut husk fly overwinter as pupae in the soil and emerge as adults from late June through early September. WHF is a mid to late season pest that occurs primarily in the northern San Joaquin Valley and Sacramento region and coast region. Mid to late maturing walnut cultivars are more severely affected by WHF than early maturing cultivars.

There are two markets for walnuts: in-shell and cracked nut. The feeding of WHF larvae stains the nutshell, making the nut unsatisfactory for sale in the in-shell market. For varieties such as the Hartley, which are best for in-shell use, the nut becomes unmarketable. WHF damage can also affect the mold in the product, again reducing its marketability.

WHF is controlled by using baited sprays combined with an OP or pyrethroid insecticide. The OP insecticides used with bait are malathion (Malathion), diazinon (Diazinon) and Lorsban. Non-OP alternatives are Pounce and Asana. Native parasites and predators attack WHF but do not prevent damaging populations.

Twospotted and Pacific Spider Mite

Twospotted Spider Mite (TSSM), *Tetranychus urticae*
Pacific Spider Mite (PSM), *Tetranychus pacificus*

The twospotted and Pacific spider mite are very similar in appearance, seasonal development, habits and damage. PSM is found specifically in the southern San Joaquin Valley while TSSM is found throughout California. Both species damage trees by destroying leaf tissue and feeding on leaf cell contents. Large mite populations cause leaves to dry up, turn brown and drop from the tree. PSM is generally held under adequate control by beneficial insects and mites. However, when these beneficials have been destroyed by broad-spectrum insecticides, particularly pyrethroid insecticides, PSM populations can rapidly increase to damaging levels. Also hot weather and water-stressed trees result in damaging levels of PSM. PSM is controlled with abamectin (Agri-Mek), clofentezine (Apollo), dicofol (Kelthane), fenbutatin-oxide (Vendex) and propargite (Omite). Resistance to Kelthane, Vendex and Omite has been reported, particularly in the southern San Joaquin Valley.

Walnut and dusky-veined Aphid

Walnut Aphid (WA), Chromaphis juglandicola
Duskey-veined Aphid (DA), Callaphis juglandis

The life cycles of both walnut and dusky-veined aphids are similar. Aphids extract large amounts of leaf fluids, causing stress on new leaf growth. Aphids cause decreased nut size and shriveled kernels at harvest. Aphids also produce a great quantity of honeydew. Sooty mold may develop on the honeydew, causing increased sunburn damage to exposed nuts. WA is held under complete control by an introduced parasitic wasp *(Trioxys pallidus)*. WA only becomes a problem when insecticides, such as Guthion and Supracide, eliminate *T. pallidus* without killing the aphids. Other OP insecticides, such as Lorsban, eliminate *T. pallidus* for a brief period of time but also WA. This allows for a re-establishment of the parasite/aphid balance. Currently pyrethroid insecticides are toxic to *T. pallidus* and other beneficial insects as well as WA and DA.

Walnut, San Jose and Frosted Scale

San Jose Scale (SJS), *Quadraspidiotus perniciosus*
Walnut Scale (WS), *Quadraspidiotus juglansregiae*
Frosted Scale (FS), *Lecanium pruinosum*

Scales suck plant juices from twigs and branches. At low populations they are not a problem; however if populations are heavy, they may affect the growth and vigor of the tree as well as increase nut sunburn. SJS injects a toxin while feeding which causes twig and branch die back. If uncontrolled, SJS and WS may cause smaller nut size and affect kernel quality. Scales are generally held under adequate control by beneficial insects. However, when these beneficial insects have been destroyed by broad-spectrum insecticides, particularly pyrethroid insecticides, scale populations can rapidly increase to damaging levels. Supracide is currently used for controlling scale. However, Esteem provides excellent scale control and can substitute for Supracide.

Current - Pest Management Program

Southern San Joaquin Valley

The southern San Joaquin Valley (Kern, Kings, Tulare, Fresno and Madera counties) contains about 41,700 bearing acres of walnuts. The southern San Joaquin Valley typically applies two to three OP insecticide applications for CM and NOW control per season to early maturing cultivars while zero to two applications are applied to mid or late season cultivars. The insecticides of choice are Lorsban, Imidan and to a lesser extent Guthion, Supracide and Penncap-M (Table 1). Supracide is often used when WS or SJS is also a problem. In recent years the IGR insecticides, Confirm and Dimilin, have increased in usage, particularly in orchards with low to moderate CM and NOW pressure. The pyrethroid insecticides, Pounce and Asana, are not used in the southern San Joaquin Valley because of the tendency of these insecticides to induce spider mite outbreaks. Spider mites are a significant pest in the southern San Joaquin Valley and one or two miticide applications per season are often used for their control. Spider mite resistance to Kelthane, Omite and Vendex has been reported in the southern San Joaquin Valley, particularly the PSM. Because of resistance or potential resistance to Kelthane, Omite, and Vendex, southern San Joaquin Valley growers have increased the use of Agri-Mek and Apollo for spider mite control. WHF is not a significant pest in the southern San Joaquin Valley. The average insecticide (material) cost per acre treated for the southern San Joaquin is approximately $92 for both early and late maturing cultivars.

Northern San Joaquin and Sacramento Region

The northern San Joaquin and Sacramento region (Merced, Stanislaus, San Joaquin, Solano, Yolo, Sacramento, Placer, Colusa, Glenn, Sutter, Yuba, Butte and Tehama counties) contain about 145,800 bearing acres of walnuts. Typically one or two OP insecticides are applied for CM and NOW control per season to early maturing cultivars while zero or one application is applied to mid or late season cultivars. The insecticides of choice are Lorsban, Imidan, Penncap-M, and to a lesser extent Guthion and Supracide (Table 2). Supracide is often used when WS and SJS are also a problem. The IGR insecticides, Confirm and Dimilin, have not been widely used except in a few orchards with low to moderate CM and NOW pressure. However, the pyrethroid insecticides, Pounce and Asana, are widely used for CM or NOW control and may replace an OP insecticide application.

Spider mites are a pest in the northern San Joaquin and Sacramento region but not to the extent as in the southern San Joaquin Valley. Only one miticide application per season is used in some but not all orchards for spider mite control. Spider mite resistance to Kelthane, Omite and Vendex has been less of a concern in northern San Joaquin and Sacramento region as in southern San Joaquin Valley. WHF can be a significant pest in mid to late bearing cultivars. Two or three bait sprays containing molasses, Nulure or Mobait plus Malathion, Diazinon, Asana or Lorsban are used for WHF control. The average insecticide (material) cost per acre treated for the northern San Joaquin and Sacramento region is approximately $49 for both early and late maturing cultivars.

Coast region

The coast region (Ventura, Santa Barbara, San Luis Obispo, Monterey, San Benito, Santa Clara, Contra Costa, Napa, Sonoma and Lake counties) contains about 14,500 bearing acres of walnuts. The coast region typically applies one or less OP applications for CM and NOW control per season. The insecticide of choice is Lorsban and to a lesser extent Guthion, Imidan and Penncap-M (Table 3). The IGR insecticides, Confirm and Dimilin, have not been widely used except in a few orchards with low to moderate CM and NOW pressure. The pyrethroid insecticides are not used in the coast region. Spider mites are not a pest in the coast region and few miticides are used. WHF is a significant pest in all cultivars in the coast region. Two or three bait sprays (bait plus Malathion or Diazinon) are used for WHF control. The average insecticide (material) cost per acre treated for the coast region is approximately $18 for both early and late maturing cultivars.

OP Free – Pest Management Program with Available Technology

The OP free programs below were constructed with currently registered insecticides for immediate implementation and without regard to resistance management consequences.

Southern San Joaquin Valley

In southern San Joaquin Valley, walnut growers would face a difficult pest management situation without the availability of OP insecticides. Higher temperatures increase the number of generations per season of many insects, including CM, NOW and mites. CM populations can complete an additional 1/2 to one generation per season while spider mites can complete many more generations when compared to walnut orchards in the coast region, northern San Joaquin or Sacramento region. More generations require a higher frequency of insecticide application for adequate control in moderate to high populations. Thus, without OP insecticides, growers would need to apply two or three pyrethroid insecticide applications for CM and NOW control per season to early maturing cultivars where CM or NOW populations are high. The use of pyrethroid insecticides would eliminate most predators of spider mites and cause significant population increases that would require the applications of two or three miticide applications, (miticides are some of the most costly pest management products.) This pest management system would be very unstable and would lead to the rapid development of spider mite resistance to all available miticides. A number of new miticides (pyrdiaben, milbemectin) are currently in development. Also, the miticidal pyrethroids [fenpropathrin (Danitol) and bifenthrin (Brigade)] that are near registration would be only effective as miticides for a short period of time because of the rapid development of resistance by the mites. In addition, the predators and parasites of WS and SJS would be largely depleted by the repeated applications of pyrethroid insecticides. Pyrethroid insecticides are not highly effective for scale control. Increased scale populations would require an application of Esteem about every other year (Table 4).

In mid to late maturing cultivars or in early maturing cultivars with a low CM population, growers would apply two or three applications of Confirm plus Dimilin. In this case, spider mites would be suppressed and held under control in many orchards by the combined actions of beneficial insects and mites and horticultural oil. However, it is anticipated that a miticide would be required about every other year. WA, DA, WS, and SJS are not controlled by either Confirm or Dimilin, but are suppressed by the horticultural oil. It is anticipated that these insects would require some measure of control about every fourth year (Table 5). The increase in insecticide usage would prevent significant damage in excess of the current level. However, the pest management system in early maturing cultivars where CM or NOW populations are high to moderate is extremely unstable and can be expected to develop uncontrollable spider mite populations within a few years of implementation.

Northern San Joaquin and Sacramento Region

Growers in northern San Joaquin and Sacramento region would reliance on pyrethroid insecticide for CM and NOW control to a greater extent than present. In early maturing cultivars where CM or NOW populations are high to moderate, growers would apply two or three applications of pyrethroid insecticide applications. The use of pyrethroid insecticides would cause an increase in spider mite populations but not to the extent as in the southern San Joaquin Valley. Although, the pyrethroid insecticides eliminate the spider mite predators, the higher humidity and slightly cooler temperatures in northern San Joaquin and Sacramento region tend to suppress spider mite populations compared to southern San Joaquin Valley. Growers would need to apply about two miticide applications. As in the southern San Joaquin Valley, the predators and parasites of WS and SJS would be largely depleted by the repeated applications of pyrethroid insecticides. Increased scale populations would require an application of Esteem about every third year (Table 6).

In mid to late maturing cultivars or in early maturing cultivars with a low CM population, growers would apply about two applications of a pyrethroid and bait for WHF and one application of Confirm plus Dimilin and horticultural oil for CM control. Without OP insecticides, control of WHF would rely on the pyrethroid insecticides. Horticultural oil would be included only to orchards that are not water stressed. Spider mites would be suppressed and held under control in many orchards by the combined actions of beneficial insects and mites and horticultural oil. However, it is anticipated that a miticide would be required about every other year. WA, DA. WS and SJS are not controlled by either Confirm or Dimilin but are suppressed by the horticultural oil. It is anticipated that these insects would require some measure of control about every third year (Table 7). The increase in insecticide usage would prevent significant damage in excess of the current level.

Coastal Region

The coast region growers would apply about three pyrethroid insecticide and bait applications for WHF control. With the elimination of the OP insecticides, pyrethroid insecticides are the only effective insecticides for WHF control. In addition, the coast region would have to apply one application of Confirm plus Dimilin and horticultural oil for CM control. Spider mites are typically not a pest in the coast region and few miticides have been used. However, with the increased use of pyrethroid insecticides for WHF control and the depletion of the beneficial insects and mites, it is anticipated that a miticide would be required about every other year. In addition, it is anticipated that WS and SJS would require an application about every third year (Table 8).

OP Free – Pest Management Program with Emerging Technology

The IPM programs below were constructed with currently registered insecticides and/or insecticides or control methods that are anticipated to be registered within four to five years. The programs are for moderate to low pest populations. If high pest populations are encountered, then one of the pyrethroid based programs would be implemented to reduce the population to a manageable level. It is anticipated that it would take only one year for a high population to be brought to a low to moderate level. Once the pest populations are reduced to moderate levels, then an IPM program with emerging technology can be implemented to maintain the pest populations below economic injury levels. The IPM program with emerging technology would produce a stable long-term program that would allow for much greater impact of beneficial insects and mites on the pest populations. The pest management program would maintain low densities over time and prevent large pest density oscillations.

Control of CM would rely on mating disruption in all areas and regions of the state. Mating disruption has been shown by past research to be very effective in maintaining CM populations at extremely low levels. However, to achieve a high level of control, a large number of pheromone dispensers must be placed high in the tree canopy. The amount of pheromone (i.e. number of dispensers) needed to provide control depends on CM population density and tree volume. The larger the tree-row volume and CM population, then a larger amount of pheromone is needed to bring about control. There are a number of currently registered CM mating disruption products (Checkmate by Consep, Isomate by Pacific BioControl and others). However, these products must be applied by hand. The only practical method to apply these dispensers high in the tree canopy is by pruning towers, which is cost prohibitive. Thus other methods of pheromone distribution must be developed for CM mating disruption to be practical. Two products, microencapsulated sprayable pheromones and aerosol puffer dispensers, are in development and would solve the problem of using pheromones in large trees. Aerosol puffers are currently registered for CM control on walnuts. However, additional research is needed on both products before they would be widely used. The aerosol puffers contain the pheromone in a pressurized can within the puffer device and emits measured amount of pheromone at regular intervals. Since the pheromone in the can does not come in contact with oxygen until the pheromone is released, there is no oxidization of the pheromone. The amount of pheromone released from one aerosol puffer is extremely large compared to the Consep or Pacific BioControl dispensers. Aerosol puffers are placed high in the tree canopy at a rate of about 1 or 2 per acre. The can of pheromone would last for the entire season. Research is focusing on the number of aerosol puffers needed per acre, the amount of pheromone emitted per puff, the time of day or night that the pheromone should be emitted, whether CM and NOW pheromone can be contained in the same aerosol puffer and others. Microencapsulated sprayable CM pheromone has been under development for a number of years. However, recent advances in the polymer bead technology has produced a microencapsulated CM product that has four to five weeks of field longevity. The advantage of a microencapsulated CM product is that it can be applied with conventional spray equipment, either ground speed sprayers or aircraft. However, considerable research is needed on all aspects of microencapsulated sprayable pheromone and it would be a number of years before there is a viable commercial product.

In addition to mating disruption, it is anticipated that two reduced risk insecticide applications would be required for CM control in the southern San Joaquin Valley and northern San Joaquin and Sacramento region while one reduced risk insecticide application would be required in the coast region (Tables 9-11). Reduced risk pesticides are a group of pesticides that exhibit low mammalian toxicity while at the same time have minimal environmental impact. Walnut growers are fortunate to have three reduced risk insecticides registered (Confirm, Esteem and Dimilin) and one other reduced risk insecticide is near registration [spinosad (Success)]. All four insecticides have different modes of action.

Confirm is an ecdysone receptor agonist and mimics the effects of ecdysone within the insect. Ecdysone is a naturally occurring insect hormone. An increase in the ecdysone level signals the insect to molt from one larval instar to the next. Insects treated with Confirm begin molting to the next instar before they are physiologically ready and cannot successfully complete the molting process. The insects are trapped within the old exoskeleton and starve to death. In practical use, Confirm is a larvicide.

Esteem is a juvenile hormone agonist that mimics the effects of the juvenile hormone within the insect. A decrease in the juvenile hormone level signals the insect to change from one stage (e.g. egg) to the next stage (e.g. larva or nymph). Insects treated with Esteem remain in their present juvenile stage and they do not develop on to the next stage. In practical use, Esteem is an ovicide. The amount of Esteem needed to prevent the pupation is much higher than the amount needed to prevent egg hatch.

Dimilin is a chitin biosynthesis inhibitor that prevents the proper development of chitin. Chitin is the structural component of an insect’s body. Dimilin prevents the developing insect embryo from synthesizing the necessary chitin to support the young larva. In practical use, diflubenzuron is an ovicide. For Dimilin to be effective, a CM egg must be oviposited on the diflubenzuron residue. The newly deposited eggs absorb the Dimilin from the bottom of the eggshell. Dimilin is not as effective if applied to eggs that are already laid.

Success is a nicotinic acetylcholine modulator that appears to increase the sensitivity of the nicotinic acetylcholine receptor site to acetylcholine, the chemical messenger that carries a nerve impulse across the synapse. Success, in effect, is a nerve poison. Mammalian nicotinic acetylcholine receptor sites appear to be different from insect nicotinic acetylcholine receptor sites. Success does not bind nor modify the mammalian receptor sites to the same degree as the insect’s receptor sites. This binding affinity may account for the differential toxicity between mammals and insects.

Since the reduced risk insecticides have different modes of action and are active against different stages of insects, the combination of two reduced risk insecticides could greatly improve their efficacy and provide a synergy of control. The combination of either Confirm or Success, which are effective larvicides, with Dimilin or Esteem, which are effective ovicides plus a narrow range horticultural oil or adjuvant (spread/sticker), should provide control equivalent to or better than the grower standard. In addition, a single combination application of reduced risk insecticides may stabilize pest control in orchards under CM pheromone mating disruption.

There are a number of new reduced risk insecticides currently under development by the agrochemical industry, many of which are targeted for registration on walnuts. The neonicotinoid insecticides [thiamethoxam (Actara), imidacloprid (Provado), Calypso and actamiprid (Assail)] are a very interesting new class of insecticides with activity against a wide range of pest species from aphids to CM. The neonicotinoid insecticides are acetylcholine agonist and mimic the action of acetylcholine at the nicotinic receptor site in the synapse. Neonicotinoid insecticides do not bind to the nicotinic acetylcholine receptor site in mammalian to the same degree as the insect's receptor sites. This differential binding affinity may account for the low mammalian toxicity. Another new reduced risk insecticide that would be registered on walnuts in the very near future is indoxacarb (Avaunt). Avaunt is a sodium channel disrupter and inhibits the flow of sodium ions into the nerve cell. Although, the mode of action of Avaunt is somewhat similar to that of DDT or the pyrethroid insecticides, Avaunt does not have the adverse effects on beneficial insects and mites or the environment as DDT or the pyrethroid insecticides. Another reduced risk insecticide is methoxfenozide (Intrepid). Intrepid is a second-generation ecdysone receptor agonist and has the same mode of action and characteristics as tebufenozide. However, Intrepid is more biologically active than Confirm and would eventually replace Confirm.

Control of NOW would rely on prompt harvest and excellent walnut blight and CM control. It is unknown at this time whether NOW mating disruption would be possible because of the oxidation problem. In addition, one reduced risk insecticide application may be required if harvest is delayed or high NOW population is observed. However, control of NOW with reduced risk insecticides is minimal at best. Since no or few pyrethroid insecticides would be applied, spider mite populations would be greatly reduced. In the southern San Joaquin Valley, one miticide application would likely be required in most years. However, growers in northern San Joaquin and Sacramento region would apply a miticide application about every third year. In the coast region no miticides would be required. WHF would be controlled with Success at very low rates of application. If CM and WHF are problems at the same time, then a higher rate of Success would control both pests if the application is properly timed. In addition, reduced risk insecticides are far less harmful to the predators and parasites of WS and SJS as well as WS and DA. The predators and parasites would, in large measure, control the aphids and scales. If WA and SJS do become a problem, the reduced risk insecticide Esteem can be applied for their control. If WA and DA become a problem, then Actara, Provado or other neonicotinoid insecticide can be applied for their control. However, it is anticipated that scales or aphids would rarely require control.

Addendum

A number of products have been registered in walnuts since the economic analysis. These include hexythiazox (Savey), pyrdiaben (Pyramite), spinosad (Success) and microencapsulated sprayable codling moth pheromone (Checkmate CM-F and MEC-CM). Savey and Pyramite will be added to the existing arsenal of miticides, e.g., propargite (Omite), clofentezine (Apollo), dicofol (Kelthane) and abamectin (Agri-Mek). Savey and Pryamite will add new modes of control and broaden the base of miticides. This should stabilize or slow the development of miticide resistance and hopefully reduce miticide costs. However, these new products will not have a major impact on walnut IPM.

The registration of Success, Checkmate CM-F and MEC-CM could have a major impact on walnut IPM. Success is a reduced risk insecticide that has minimal impact on beneficial insects and mites. Although, Success is only marginally effective against codling moth and as such will be used only as a rotational insecticide with tebufenozide (Confirm) in reduced risk IPM programs. The rotation of Confirm and Success will delay the development of resistance to either insecticide and prolong their field lives. Success will have a major impact on walnut husk fly control. Success is highly effective against walnut husk fly and will provide an immediate OP alternative. Success will likely become the insecticide of choice for growers not only because of its walnut husk fly efficacy but also cost. Checkmate CM-F and MEC-CM could have a major impact on walnut IPM. Checkmate CM-F and MEC-CM are microencapsulated sprayable codling moth pheromone. They are reduced risk insecticides that have minimal or no impact on beneficial insects and mites. However, a great deal of research is still needed before the potential of these products will be fully realized. It is anticipated that in a few years, microencapsulated sprayable codling moth pheromone will gain a major share of the codling moth control market in California walnuts.

Table 1. Insecticide and Miticide Use on Walnuts in the Southern San Joaquin Valley of California, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Costs
abamectin (Agri-Mek)	79	7,607	19.4	$397,836
azinphosmethyl (Guthion)	14,318	8,756	22.3	$297,528
chlorpyrifos (Lorsban)	37,903	21,128	53.8	$717,118
clofentezine (Apollo)	469	3,597	9.2	$179,181
diazinon (Diazinon)	560	313	0.8	$5,173
dicofol (Kelthane)	3,941	2,312	5.9	$110,813
diflubenzuron (Dimilin)	771	3,022	7.7	$61,709
esfenvalerate (Asana)	8	169	0.4	$1,473
fenbutatin-oxide (Vendex)	288	469	1.2	$15,952
horticultural oil (Petroleum Products)	36,673	10,168	25.9	$20,170
malathion (Malathion)	843	277	0.7	$4,614
methidathion (Supracide)	6,935	3,630	9.2	$194,179
methyl parathion (Penncap-M)	11,578	11,832	30.1	$180,391
phosmet (Imidan)	53,217	12,173	31	$551,324
propargite (Omite)	31,930	14,486	36.9	$619,443
tebufenozide (Confirm)	2,897	11,144	28.4	$273,766

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre planted for the Southern San Joaquin valley is about $92.40.

Table 2. Insecticide and Miticide Use on Walnuts in the Northern San Joaquin and Sacramento Region of California, 1999

Material*	Lb (ai)	Acres Treated	% Acres Treated	Cost
abamectin (Agri-Mek)	10	4,942	3.5	$49,930
azinphosmethyl (Guthion)	19,483	12,714	9	$404,865
chlorpyrifos (Lorsban)	102,575	58,623	41.5	$1,940,723
clofentezine (Apollo)	275	2,494	1.8	$105,023
diazinon (Diazinon)	6,908	3,815	2.7	$63,829
dicofol (Kelthane)	2,905	1,676	1.2	$81,690
diflubenzuron (Dimilin)	776	3,235	2.3	$62,110
esfenvalerate (Asana)	1,674	35,951	25.4	$304,307
fenbutatin-oxide (Vendex)	3,232	5,847	4.1	$178,858
horticultural oil (Petroleum Products)	48,494	20,656	14.6	$26,672
malathion (Malathion)	14,506	3,571	2.5	$79,350
methidathion (Supracide)	3,964	2,870	2	$111,005
methyl parathion (Penncap-M)	47,737	56,298	39.8	$743,738
naled (Dibrom)	8,461	8,089	5.7	$88,583
permethrin (Pounce, Ambush)	4,605	21,823	15.4	$310,863
phosmet (Imidan)	86,974	23,678	16.8	$901,051
propargite (Omite)	68,429	37,088	26.2	$1,327,525
tebufenozide (Confirm)	1,758	6,722	4.8	$166,134

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre planted for the Northern San Joaquin and Sacramento region is about $49.14.

Table 3. Insecticide and Miticide Use on Walnuts in the Coast Region of California, 1999

Material*	**Lb (ai)**	**Acres Treated**	**% Acres Treated**	**Cost**
abamectin (Agri-Mek)	1	36	0.6	$3,255
azinphosmethyl (Guthion)	490	333	5.2	$10,174
chlorpyrifos (Lorsban)	2,283	2,248	35	$43,201
diazinon (Diazinon)	492	283	4.4	$4,546
esfenvalerate (Asana)	5	55	0.9	$969
horticultural oil (Petroleum Products)	7,034	603	9.4	$3,869
malathion (Malathion)	2,971	1,647	25.6	$16,254
methyl parathion (Penncap-M)	431	582	9.1	$6,709
phosmet (Imidan)	859	333	5.2	$8,898
propargite (Omite)	254	130	2	$4,935
tebufenozide (Confirm)	101	389	6.1	$9,582

* Pesticides used on less than 1% of the total statewide acreage are excluded from tables (Dept. Pesticide Regulation – Pesticide Use Reports). Average insecticide (material) cost per acre planted for the Coast region is about $ 17.76.

Table 4. Insecticide and Miticide Use in an OP free IPM System with Available Technology on Walnuts in the Southern San Joaquin Valley for Early Maturing Cultivars with High CM and NOW Populations

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
esfenvalerate (Asana XL)	1 pt	3	CM	Increased spider mites may result
abamectin (Agri-Mek 0.15EC) + Horticultural oil at 1.0% by volume	1 pt	1	Spider mites	Two or more miticides per year may be needed
clofentezine (Apollo 4SC)	1/4 pt	1/2	Spider mites	
propargite (Omite 30W)	10 lb	1/2	Spider mites	
pyriproxyfen (Esteem 0.86 EC)	1 pt	1/2	Scales	About every other year

Table 5. Insecticide and Miticide Use in an OP free IPM System with Available Technology on Walnuts in the Southern San Joaquin Valley for Mid to Late Maturing Cultivars or Early Maturing Cultivars with Low to Moderate CM and NOW Populations

Material	**Rate Form./ac**	**# Appl./ Season.**	**Pest**	**Notes**
tebufenozide (Confirm 2F)	1 pt	1	CM	
+				
Horticultural oil at 1.0% by volume				
tebufenozide (Confirm 2F)	1 pt	2	CM	
+				
diflubenzuron (Dimilin 2L)	1 pt			
+				
Horticultural oil at 1.0% by volume				
abamectin (Agri-Mek 0.15EC)	1 pt	1/2	Spider mites	About every other year
+				
Horticultural oil at 1.0% by volume				
endosulfan (Thiodan 50WP)	4 lb	1/4	Aphid	About every fourth year. May cause TSSM outbreaks
pyriproxyfen (Esteem 0.86 EC)	1 pt	1/4	Scales	About every fourth year

Table 6. Insecticide and Miticide Use in an OP free IPM System with Available Technology on Walnuts in the Northern San Joaquin and Sacramento Region for Early Maturing Cultivars

Material	**Rate Form./ac**	**# Appl./ Season.**	**Pest**	**Notes**
esfenvalerate (Asana XL)	1 pt	2	CM	Increased spider mites may result
or				
permethrin (Pounce 3.2 EC)	1 pt			Increased spider mites may result
propargite (Omite 30 W)	10 lb	1	Spider mites	
clofentezine (Apollo 4SC)	1/4 pt	1/2	Spider mites	
pyriproxyfen (Esteem 0.86 EC)	1 pt	1/3	Scales	About every third year

Table 7. Insecticide and Miticide Use in an OP free IPM System with Available Technology on Walnuts in the Northern San Joaquin and Sacramento Region for Mid to Late Maturing Cultivars

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
esfenvalerate (Asana XL)	1/2 pt	2	WHF	Increased spider mites may result
or				
permethrin (Pounce 3.2 EC)	1/2 pt			Increased spider mites may result
+				
NuLure	1 gal			
tebufenozide (Confirm 2F)	1 pt	1	CM	
+				
diflubenzuron (Dimilin 2L)	1 pt			
+				
Horticultural oil at 1.0% by volume				
propargite (Omite 30 W)	10 lb	1/3	Spider mites	About every other year
endosulfan (Thiodan 50WP)	4 lb	1/3	Aphid	About every third year
pyriproxyfen (Esteem 0.86 EC)	1 pt	1/3	Scales	About every third year

Table 8. Insecticide and Miticide Use in an OP free IPM System with Available Technology on Walnuts in the Coast Region

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
esfenvalerate (Asana XL)	1/2 pt	3	WHF & some CM	Increased spider mites may result
or				
Pounce 3.2 EC	1/2 pt	3		Increased spider mites may result
+				
NuLure	1/2 gal			
tebufenozide (Confirm 2F)	1 pt	1	CM	
+				
diflubenzuron (Dimilin 2L)	1 pt			
+				
Horticultural oil at 1.0% by volume				
propargite (Omite 30 W)	10 lb	1/3	Spider mites	About every other year
pyriproxyfen (Esteem 0.86 EC)	1 pt	1/3	Scales	About every third year

Table 9. Insecticide and Miticide Use in an IPM Program with Emerging Technology for Walnuts in the Southern San Joaquin Valley

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
CM pheromone disruptionCM (Puffers or micro-encapsulated pheromone)				
tebufenozide (Confirm 2F)	2 pt	2	CM and NOW	
or				
spinosad (Success 2SC)	1/2 pt	2		
+				
diflubenzuron (Dimilin 2L)	1 pt			
+				
Horticultural oil at 1.0% by volume				
abamectin (Agri-Mek 0.15EC)	1 1/2 pt	1	Spider mites	
+				
Horticultural oil at 1.0% by volume				
or				
clofentezine (Apollo 4SC)	1/4 pt	1/2		
pyriproxyfen (Esteem 0.86 EC)	1 pt	1/4	Scales	About every fourth year
imidacloprid (Provado 1.6 F)	1/2 pt	1/4	Aphids	About every fourth year

Table 10. Insecticide and Miticide Use in an IPM Program with Emerging Technology for Walnuts in the Northern San Joaquin and Sacramento Region

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
CM pheromone disruption CM (Puffers or micro-encapsulated pheromone)				
tebufenozide (Confirm 2F)	2 pt	2	CM and NOW	
or				
spinosad (Success 2SC)	1/2 pt	2		Success may be used if WHF is a problem
+				
diflubenzuron (Dimilin 2L)	1 pt			
+				
Horticultural oil at 1.0% by volume				
propargite (Omite 30 W)	10 lb	1/3	Spider mites	About every third year
pyriproxyfen (Esteem 0.86 EC)	1 pt	1/4	Scales	About every fourth year
imidacloprid (Provado 1.6 F)	1/2 pt	1/4	Aphids	About every fourth year

Table 11. Insecticide and Miticide Use in an IPM Program with Emerging Technology for Walnuts in the Coast Region

Material	Rate Form./ac	# Appl./ Season.	Pest	Notes
CM pheromone disruption CM (Puffers or micro-encapsulated pheromone)				
GF-120	1 pt	3	WHF	spinosad + bait form.
tebufenozide (Confirm 2F)	2 pt	1	CM	
or				
spinosad (Success 2SC)	1/2 pt	1		
+				
diflubenzuron (Dimilin 2L)	1 pt			
+				
Horticultural oil at 1.0% by volume				

Appendix B: Mathematical Model

The economic model uses three parameters to summarize the production-related consequences resulting from the use restrictions placed on OP pesticides: per-acre yield change, per-acre cost change, and the fraction of total acres using OP pesticides. Changes in per-acre yield and cost for each commodity alter the production possibilities of growers and hence affect the availability and the price of commodities. These changes in yields and costs are applied to the percentage of acres that use OPs and the resulting changes in welfare are calculated.

Total economic welfare is defined as the sum of consumer and producer surplus. The economic impact of restricting OP use is calculated as the difference in economic welfare occurring with and without the use of OP pesticides. To calculate the changes in producer and consumer surplus that occur under cancellation of OP pesticides, a model of market activity must be developed to determine how such a cancellation would alter existing market equilibrium (Lichtenberg et.al., Sunding, Zilberman et.al., Metcalfe et. al.).

To account for regional heterogeneity in production conditions, production for each of the n commodities examined occurs in one of m production regions with A_{ij} denoting the number of acres devoted to production of crop i in region j. Land within a region is assumed homogeneous with regard to quality in the sense that maximum per-acre yields are constant, but it is assumed that there are competing uses for land and that the cost of acquiring land is positive. An adjustment cost of expansion is specified, $g_{ij}(A_{ij})$, in order to model the notion that the expansion of acreage is limited in the short run by costs associated with converting acres from other uses where g_{ij} is twice differentiable, increasing, and strictly convex. Thus, although the possibility for expanding output on an acre is limited, production can be increased by acquiring additional acres.

Production is calculated as $q_{ij} = y_{ij} A_{ij}$, where y_{ij} is the crop yield per-acre. The domestic market demand for crop i is denoted by $p_i^d(q_i^d)$ and excess foreign demand (or supply) is denoted by $p_i^e(q_i^e)$, where $q_i^d = \sum_{j=1}^{m} q_{ij} + q_i^e$, and $q^e{}_i$ is net exports for each commodity i. Profit net of land costs for crop i in region j is thus given by $y_{ij} A_{ij}(p_i - c_{ij} / y_{ij})$, where p_i represents the equilibrium market price and c_{ij} is the per-acre production cost. For each commodity considered, it is assumed that markets are perfectly competitive, and that producers take price as fixed when making their output decisions.

In the *status quo* (when OP pesticides are being used), and assuming profit-maximizing behavior, the acreage for each crop and region combination is then determined by the following conditions,

$$
(1) \qquad
\begin{aligned}
& y_{ij}\left(p_i - \frac{c_{ij}}{y_{ij}}\right) - g'_{ij}(A_{ij}) = 0 \\
& p_i^d(q_i^d) - p_i = 0 \\
& p_i^e(q_i^e) - p_i = 0 \\
& q_i^d + q_i^e = \sum_{j=1}^{m} y_{ij} A_{ij},
\end{aligned}
$$

where g'_{ij} represents the first derivative of g with respect to a change in production acres. The first of these conditions implies that acreage in each region will increase until the marginal gains from doing so are exhausted. The next two conditions ensure market clearing in domestic and foreign markets and the last equates U.S. production with the domestic and foreign consumption of U.S. commodities.

Only a percentage of the crop acreage planted in each region receives an application of OP pesticides. This fact is accounted for by letting α_{ij} represent this fraction, and defining

$$A_{ij}^{u} = \alpha_{ij} \cdot A_{ij},$$

$$A_{ij}^{n} = (1 - \alpha_{ij}) A_{ij},$$

as the total number of OP user and OP non-user acres, respectively. When OP use is restricted, then producers who used OP pesticides on their acreage must adopt a non-OP pest management program. Production of each commodity in the absence of OP pesticides results in a change in per-acre yields and per-acre production costs on those acres that were using OP pesticides. These changes are denoted as dy_{ij} and dc_{ij} respectively. Note that yield and cost changes vary by crop and by region thereby accounting for existing differences in OP use and in the overall importance of OP pesticides.

The impact of yield and cost changes on the market equilibrium conditions are calculated by totally differentiating each expression in equation (1). Total differentiation, together with some algebraic manipulation, yields the following for all acres adopting the non-OP alternative

$$(2) \qquad dp_i \frac{A_{ij}^{u}}{p_i} - \frac{dA_{ij}^{u}}{\varepsilon_i} = \frac{A_{ij}^{u}}{y_{ij} p_i} \left(y_{ij} d^{u} \left(\frac{c_{ij}}{y_{ij}} \right) - dy_{ij} \left(p_i - \frac{c_{ij}}{y_{ij}} \right) \right),$$

where ε_i is the elasticity of supply for crop i and $d^u\left(\frac{c_{ij}}{y_{ij}}\right)=\frac{c_{ij}+dc_{ij}}{y_{ij}+dy_{ij}}$, is the change in marginal cost (shift in the supply curve) for OP users adopting the non-OP alternative. Changes in the acres that did not use OP pesticides are determined by the relationship

(3) $$dp_i\frac{dA_{ij}^n}{p_i}-\frac{dA_{ij}^n}{\varepsilon_i}=0.$$

Changes in market clearing conditions are given by

(4) $$\begin{aligned} &dp_i\frac{q_i^d}{p_i}-\frac{dq_i^d}{\eta_i^d}=0 \\ &dp_i\frac{q_i^e}{p_i}-\frac{dq_i^e}{\eta_i^e}=0 \\ &dq_i^d+dq_i^e-\sum_{j=1}^{m}y_{ij}\left(dA_{ij}^u+dA_{ij}^n\right)=\sum_{j=1}^{m}A^u{}_{ij}dy_{ij} \end{aligned}$$

where η_i^d and η_i^e are the domestic demand and net trade elasticities respectively.

Using the experts' opinions on changes in per-acre yields and costs, the conditions in (2) through (4) can be solved for dp_i, dA_{ij}^u, dA_{ij}^n, dq_i^d, and dq_i^e. This approach is useful because it does not require knowledge of the functional forms of the acreage adjustment functions and market demand functions and thus, it is not necessary to conduct detailed econometric analyses of supply and demand relationships in each market. However, the obvious disadvantage is that for large changes in yields and costs, the approximation obtained by totally differentiating equation (1) will be less accurate.

Measures of consumer and producer welfare are defined. Let

(5) $$CS_i(q^d{}_i) = \int_0^{q^d{}_i} p^d{}_i(\tau)d\tau - p^d{}_i(q^d{}_i)q^d{}_i \,,$$

represent the welfare to domestic consumers resulting from consumption of crop *i*, which is the usual definition of consumer surplus. Producer profit is used to define producer surplus as

(6) $$PS_{ij}^k(y_{ij}, c_{ij}, q_{ij}) = q_{ij}^k\left(p_i - \frac{c_{ij}}{y_{ij}}\right) - g_{ij}\left(\frac{\alpha^k{}_{ij} q_{ij}^k}{y_{ij}}\right).$$

Producer group *k* is used to represent the two groups of producers in the analysis: OP users and OP non-users. Changes in consumer surplus and producer surplus for each crop and region combination can then be calculated by totally differentiating the expressions in equations (5) and (6). Changes in the welfare effects for foreign consumers and producers are not calculated in this analysis.

Differentiating expression (5) with respect to q_i^d yields $-(p_i / \eta_i^d)dq_i^d$. Thus, since $\eta_i^d < 0$, a reduction in aggregate market output unambiguously reduces consumer surplus, and this reduction is larger for smaller values of $\left|\eta_i^d\right|$. This result shows that when demand is inelastic, even a small reduction in output can lead to a significant increase in price and therefore consumers will incur high costs from an OP ban.

Changes in the profits of producers are calculated in three parts: 1) the changes in total revenues received by producers, $dTR = qdp + (p + dp)dq$; 2) the changes associated with changes in production costs, $dPC = qd\left(\frac{c}{y}\right) + \left(\frac{c}{y}\right)dq$; and 3) the changes in production costs due to the resulting changes in acreage,

$dAC = g'\cdot\left(\frac{\alpha}{y}\right)dq + g'\cdot\left(\frac{-\alpha q}{y^2}\right)dy = \alpha\left(p-\frac{c}{y}\right)dq - \left(\frac{\alpha q}{y}\right)\left(p-\frac{c}{y}\right)dy$. Therefore, the change in producer surplus for former OP users is represented as

$$(7)\qquad dPS^u{}_{ij} = q_{i,j}dp_i + \left[(1-\alpha_{ij})\left(p_i - \frac{c_{ij}}{y_{ij}}\right) + dp_i\right]dq^u_{ij} + \alpha_{ij}A_{ij}\left(p_i - \frac{c_{ij}}{y_{ij}}\right)dy_{ij} - q^u_{ij}d^u\left(\frac{c_{ij}}{y_{ij}}\right).$$

There are no yield and cost changes for non-OP users and therefore changes in producer surplus for these growers is

$$(8)\qquad dPS^n{}_{ij} = q_{i,j}dp_i + \left[\alpha_{ij}\left(p_i - \frac{c_{ij}}{y_{ij}}\right) + dp_i\right]dq^n_{ij}.$$

The total change in producer surplus for all producers is obtained by summing equations (7) and (8).

Equation (7) demonstrates that the welfare cost to producers who were using OP pesticides depends on four components. First an increase in price leads to an increase in revenues. Second, a reduction in aggregate output leads to a reduction in revenues and is represented by the second term in equation (7), while the third and fourth terms show that the resulting decrease in yield and increase in cost leads to a reduction in surplus. For non-OP using producers who are unaffected by changes in yield and cost, equation (8) indicates that these producers unambiguously gain when price, and therefore aggregate production, increase. This simply reflects the fact that producers who are unaffected by restrictions receive a higher price for each unit sold while generating the same yield and incurring the same cost as before restrictions were imposed.

There is no way to know with certainty what will be the eventual effects resulting from OP use restrictions. Two separate groups of experts were surveyed and their opinions as to eventual yield and cost changes are provided in the previous section. Economic impacts are calculated twice, once using the estimates provided by the focus group participants and once using the estimates provided by the UC specialists. The results from these two calculations provide a range for the potential annual welfare changes resulting from increased regulation.