Pear Pest Management Alliance

(A Pear Pest Management Evaluation)

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by the

California Pear Advisory Board
(in cooperation with the Pear Pest Management Research Fund
and California Pear Growers)
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California Pears

PRODUCTION FACTS

- The United States is the world's second largest pear producer, with USDA statistics reporting U.S. production in 1998 at 833,000 metric tons, with an average of 900,000 metric tons per year for the last 10 years. California's annual production is approximately 300,000 short tons, about 33% of US production.

- There are approximately 300 growers growing pears on just under 20,000 acres. The predominant variety is Bartlett. The five-year average cash value of pears at the first delivery point is $514,314,000.[1] The majority of pears produced in California are found in the northern third of the state. From over 36,000 acres in the late1970s, California Bartlett acreage fell to less than 20,000 in the early 1980s and has stabilized at that level.

- The average cost to produce an acre of pears amounts to $7,375[2] per acre.

- Roughly two-thirds of California's annual Bartlett production is canned by processors, with tight restrictions on insect infestation and disease damage levels. This makes control of the pear's key insect pest, the codling moth, essential to economic production of pears. An average of 20-25% of the crop is shipped to the fresh market, where buyers and consumers demand fruit that is free of insects, disease, damage, and that has a clean finish. Potential damage from russet, scab, surface-feeding insects, and codling moths, must be minimized in order to produce fruit suitable for the fresh market. The remaining 10-15% is utilized in other processed products such as juice, concentrate, frozen, baby food, dried pears and fermentation.[1]

PRODUCTION REGIONS

The majority of pears produced in California are found in the northern third of the state in the counties of Sacramento, Yolo, Solano, San Joaquin, Mendocino, Lake, Yuba and Sutter. Other minor producing areas are the counties of El Dorado, Placer, Contra Costa, Madera, Fresno, Tulare and the Littlerock area of Los Angeles County.

CULTURAL PRACTICES

European Cultivars

The predominant summer variety of pear grown in California is the smooth skinned Bartlett (Williams) averaging 285,310 short tons for the last five years.[1] Other varieties of European summer pears are the Butirra Precoce Morettini (Juno) (earlier than Bartlett), Red Sensation, Max Red and Clapp Favorite (Rosired or Stark Crimsom). The predominant Fall pear in California is Bosc with about 16,000 tons being produced yearly. This variety has the potential to increase to 25,000 tons/year. Other Fall pears in order of importance are Comice, Seckel, Beurre Hardy (French Butter Pear) and Forelle.

The above varieties are grafted onto rootstocks. Rootstock selection is based on cultivar compatibility, soil texture and drainage, pests (primarily fire blight, oak root fungus and pear decline susceptibility), and weather conditions of the orchard site. The more common European rootstocks are Winter Nelis, *Pyrus betulifolia* and the *Old Home X Farmingdale* crosses. Less common are *P. calleryana* and Bartlett.

Asian Cultivars

While their plantings are small relative to European pears, Asian pears makeup an important part of some pome and stone fruit growers' marketing mix. They are planted throughout the Sacramento and San Joaquin Valleys. Some of the varieties are Ya Li, Shinseiki, Kosui, Hosui, 20th Century and Tsu Li.[3]

Pears are most productive on loam-textured, deep uniform soils. Although, many orchards or portions of orchards are planted on less than ideal sites where soil modification or special treatment may be necessary. Sprinkler irrigation is the predominant form of irrigation with a few orchards still using flood and furrow irrigation where these methods are practical.

Pears begin blooming in the Early Districts of Sacramento, San Joaquin, Yolo, Sutter, Yuba and Solano about the 15th of March. The major varieties of Bartlett and Bosc are self-fruiting (parthenocarpic). Most California growers do not use cross-pollinizers or bees.

For over 25 years the California Bartlett pear industry has shown its commitment to the principles of pesticide risk reduction through innovation in pest management and the implementation of integrated pest management (IPM). Pear growers initiated and supported financially the development of one of the first formal tree fruit IPM programs in the nation, capped by the publication of the Pear IPM Manual in 1974.

The past eight years have witnessed new energies devoted to innovation in pear pest management. In 1992 growers and processors joined together to form the Pear Pest Management Research Fund (PPMRF) specifically empowered to seek safer, more efficient ways to manage pests. PPMRF and the Pear Advisory Board, supported entirely by grower checkoffs, together fund over $200,000 in pear IPM research every year.

The California pear industry is committed to implementing environmentally sound pest management practices. To that aim it has supported research and implementation projects into pheromone-based mating disruption for codling moth control for the past 10 years that has steadily moved us in the adoption of this new technology. Extensive small plot trials were started in 1987 in Yuba and Lake Counties. These studies showed pheromones to be successful if codling moth populations were at low to moderate levels. To improve efficacy, larger scale pheromone projects were designed to obtain codling moth control for a more sustained period than possible in small plot trials. The Randall Island Project, winner of the State of California's IPM Innovator award, was initiated in 1993 and the Areawide Mendocino Project in 1996. These ongoing projects have achieved a 75% organophosphate reduction for codling moth control. Adoption of mating disruption requires an increase in the information base for growers because of the novelty of the approach, the increased rates of required monitoring, and the potential for pest outbreaks normally not found in organophosphate-dominated systems. To increase adoptions in all pear regions of California we will start new implementation projects in each of four pear growing regions in 1999. Simultaneously, the pear industry is supporting other control measures in a multi-faceted approach to reduce codling moth populations. The efficacy of puffers, a new pheromone dispenser technology, began being studied in large scale trials in 1999. Foreign exploration and importation of natural enemies of codling moth has taken place since 1992. Sanitation, the removal of pears immediately after harvest, has been studied since 1993.

In the area of disease control the pear industry has supported Dr. Steve Lindow's research into biological agents for russet and fireblight control since 1982. His work culminated with the registration of a naturally occurring organism registered as BLIGHT BAN A-506 which acts as a competitive exclusion agent. We are presently supporting research into modeling epidemiology and disease risk for better timing pear scab control measures and looking at the potential for urea and/or lime sulfur foliar sprays and liming for reducing pear scab inoculum.

We are committed to moving into a more ecologically-based pest management practices and, to that effect, we have invested research and implementation funds. It takes time to conduct research and iron out all the problems during implementation. Our record shows progress made and our commitment to continue in this direction. The long-term goal for the pear industry is to develop an integrated pest management system that provides economic control in an environmentally safe manner.

INSECTS/CONTROLS

In California pears, the major insect pests are codling moth, pear psylla, and spider mites. Other secondary pests that occasionally cause damage are leafrollers, true-bugs (boxelder, lygus and stink bugs), mealybugs, russet mites and San Jose scale.

Codling Moth, *Cydia pomonella*

The pear pest of primary importance in California is codling moth (CM) due to its lack of effective biological control agents, direct attack on pears, and effects on fruit storage mandating control efficacy at less than 1% damage. While some of the other pests may also directly damage the fruit, the frequency and intensity are typically far less and easier to control.

Codling moth overwinters as a full grown larvae in an inactive state called diapause. The larvae pupate inside cocoons in early spring. Shortly thereafter they emerge as moths. Mating does not occur until sunset temperatures reach 62°. Each mated overwintering female deposits 30 to 70 eggs. Eggs hatch when an average of 158 degree-days have accumulated from the time that they were layed. Young larvae bore into the fruit within the first 24 hours after hatching and tunnel to the core, where they feed on developing seeds. In early stages of fruit development, infested fruit normally fall to the ground. Later in fruit development, infested fruit rot from the core out making it difficult if not impossible to sort on a packing line. Infested fruit in canning pears rot first in the ripening process, infecting other pears in the bin with rot, causing extensive loss of case-yield per ton.[8] Canners have pulled CM-infested bins of pears from the ripening rooms upon completion of ripening to find larvae crawling from pear to pear.

Monitoring: Pheromone traps are used extensively to monitor codling moth adults and coupled with degree-day modeling are used to time treatment applications.

Chemical Controls
(All insecticide applications are assumed to be applied by ground unless otherwise noted.)

Pre-harvest chemical applications are an important component in the control of CM in pears. The following chemicals are used in conventional insecticide programs.

- Guthion *Azinphos-methyl* - (50% wettable powder) 14 days PHI. (2-3 day REI depending on rainfall and 14day REI for activities where there is foliage contact) Normally applied 3 times at the 11/2-pound rate AI or 4 times at the 1 pound rate AI. Azinphos-methyl is the most effective material for codling moth control. It is somewhat selective against predaceous mites but toxic to generalist predators. It is less disruptive to natural pear psylla enemies such a lacewing. It is the preferred material because of its longer residual. Use in 1998 was greatly reduced because of label restriction imposed by SB-950.

- Penncap-M *Methyl Parathion* - Tree fruit uses canceled by EPA December 31 1999.

- Imidan *Phosmet* - (70% wettable powder) 7 days PHI. This was a third alternative OP for CM control until the cancellation of methyl parathion In 1995 it was used on about 15% of the pear acreage. It was used considerably more in 1998 just previous to harvest because of the Guthion 45-day REI. Also, 1998 was a low population codling moth year. Researchers,[5] farm advisors and PCAs advise this insecticide would not carry the orchard through the picking season without some CM damage in a normal year. A full rate application is not considered to have the residual of an Azinphos-Methyl or Methyl Parathion application. Thus, it is a poor choice for heavy CM populations. A PH of 6.5 tank-mixing water is necessary to achieve optimal results. This is sometimes hard to achieve without buffers, as farm well waters are notorious for their hard water. It has the same CM resistance problems as Guthion.

Chemical Resistance

In Sacramento County the highest levels of resistance are found at 12-fold, azinphos-methyl is typically applied 4 times at 1.0-1.5 lb. AI per acre. Four applications at 1.5 lb. per acre represent the legal maximum rate for the season. *Note change above for the 2000 season.* In some orchards, a fifth application with another organophosphate is necessary to obtain acceptable levels of control.[4]

In addition, resistance to other insecticides has been found in the azinphos-methyl resistant populations of codling moth. Whereas multiple mechanisms of detoxification are apparently involved, resistance to a broad number of materials and classes of insecticides has already been documented by Dr. S. Welter, UC Berkeley. Correlated resistance has been found in other organophosphates (diazinon, phosmet), carbamates (carbaryl), chlorinated hydrocarbons (DDT), insect growth regulators (fenoxycarb), and pyrethroids (esfenvalerate and fenpropathrin). As such, low levels of resistance appears to exist for many currently registered materials and to some non-registered materials.

Alternatives

An alternative approach to a full insecticide program is the use of synthetic pheromone sources to prevent the successful mating of pest species. If mating can be disrupted, then reproduction is prevented, thus minimizing infestations of the crop due to lower population levels of the pest. A variety of synthetic pheromone sources are placed within the orchard at a rate of 120 to 400 dispensers per acre depending on the product for codling moth. Recent technological breakthroughs in dispenser efficacy and longevity have made the use of pheromone mating disruption programs highly effective for control of codling moth.

After 5 years of limited field testing that started in 1987, large field implementation trial using mating disruption as its core was started in Sacramento County in1993 and in Mendocino County in 1996. Replacement of organophosphate insecticides or its dramatic reduction in use rate have the following benefits in terms of environmental or worker risk reduction:

- increased safety to farm workers and adjacent urban/suburban areas
- enhanced selectivity with dramatically reduced effects on natural enemies
- improved opportunities for biological control of codling moth and other pestiferous organisms in orchards
- minimization of insecticide residues on fruit

- operational advantages: (no pre-harvest intervals, no farm worker re-entry intervals)

The large scale was necessitated because resistance was being approached at a population level as well as empirical data had shown improved control associated with larger test areas. The hypotheses for improved control associated with larger treatment areas include a reduction in edge-to-area ratio, improved general population suppression, and a more uniform distribution of pheromone.

The Randall Island Project located in Sacramento County, one of the largest implementation efforts in US tree crops for multiple growers, was initiated in 1993. Six growers voluntarily combined efforts within 760 contiguous acres to implement pheromone mating disruption of codling moth. A second areawide project was initiated in Mendocino County with 400 acres in 1996, increasing to 900 acres by 1998 with an 130 additional acres to be added in 1999. In these projects, University researchers have worked with growers and their professional pest control advisors, to fully implement areawide mating disruption programs. The goals of the program are:

- to judge the success of pheromone control over a large genetically isolated area
- to foster grower-run coalitions
- to provide technical support to growers during the years of transition to pheromone-base control programs.
- to demonstrate the larger benefits of restructuring pest management of codling moth for reducing use of pesticides for secondary pests
- to combat the increasing resistance of codling moth to the organophosphate insecticide azinphos-methyl, and through cross-resistance, other conventional compounds and insect growth regulators. Using weekly-pooled information, the growers in conjunction with University of California personnel implemented a multi-year program to reduce organophosphate use. The first year in each project azinphos-methyl use was reduced by 50 to 66%, whereas a 70 to 85% reduction was obtained in successive years. Furthermore, growers and PCA's involved in the two areawide projects have adopted mating disruption in an additional 1,000 acres in Sacramento County and 205 acres in Mendocino County.

These ongoing projects have demonstrated that organophosphate insecticides for codling moth control can be reduced by 75% on average. **Total elimination is not feasible at this time. Supplemental OP and IGR insecticide use for codling moth control are needed when populations are too high, the orchards are too small, in hilly terrain, have wind-exposed boarders, are not uniformly planted or the orchard is close to a source of codling moth such as backyard apple and pear trees, bin piles, packing sheds or a walnut orchard.**

Since 1997 the puffers, a new system to dispense the pheromone was being investigated in 160 acres in Lake County. Dispenser location, densities of puffers deployed, release rate of codlemone and timing of release were fine-tuned and culminated with the registration in 1998 of the Paramount Puffer. Efficacy trials and expansion of puffer plots will continue in Lake and Mendocino counties during the 2000 crop year.

In short, the dramatic 70 to 85% reduction in use of organophosphate insecticides following a three-year implementation of pheromone mating disruption has met most risk reduction criteria for farm workers, adjacent urban areas, and non-target arthropods within the orchards. The success of mating disruption depends on an intensive monitoring program to determine when and where supplemental control is needed and on growers obtaining confidence in this new approach. Presently, 15% of the pear acreage is under mating disruption. Efforts to fine-tune monitoring protocols and increase grower confidence and adoption will take place in 1999 with additional implementation projects in three new regions. The long term success of this program requires the careful training of local grower groups. The notion of strong grower involvement combined with a team approach by University academic and extension personnel makes the effort collaborative. This ensures the continuation of the program in years to come by grower run groups. To that effect the Ukiah Valley IPM Pear Growers in the Mendocino County area-wide pear grower group was formed to run the Mendocino Areawide project. Each region attempting to develop a regionally-based, large-scale program demonstrates grower and PCA commitment to the program.

Continued success also depends on the development of secondary pest strategies for leafroller and plant bug controls with no detrimental effects to the beneficial species that build up in the absence of organophosphate insecticide use. These beneficials can provide near complete, non-chemical control of other principal pear pests such as pear psylla and spider mites. Control of secondary pests such as leafrollers by biological means or the registration of insect growth regulators is absolutely critical for the economic viability of pheromones in codling moth management.

Biological Control

Opportunities for biological control have never been greater since the introduction of alternatives to azinphos-methyl for control of codling moth. Codling moth parasitism levels in California are very low, ranging from 0-10%. In Eurasia, were codling moth originates, parasitism levels are higher ranging from 30 to 60%. Successful introduction of parasitoids would reduce codling moth populations thus making mating disruption a more effective control measure given that mating disruption is not as effective with high populations.

Classical biological control research funded by the California pear industry has helped procure, rear, and release several species of exotic parasitoids from several locations in Central Asia, China and Europe. The compatibility of each parasitoid species with codling moth suppression is assessed before field release is considered. Of the eight species acquired, three species have been released in several locations in California. Liotryphon caudatus, has been field released since 1992 and Mastrus ridibundus since 1995. Both species have been recovered from a number of release sites and in 1997 they were recovered in orchards were no in-season releases had taken place, indicating successful overwintering of the parasitoid populations in the field. A third species Microdus rufipes has been released in small numbers since 1995. Reproductive successful populations now appear to be present in California with M. ridibundus being the most active in pear orchards, generating up to 38% parasitism of the overwintering codling moth in trap bands.

Cultural Controls

On-going research by Dr. Robert Van Steenwyk at UC Berkeley with post-harvest control of codling moth using sanitation techniques has shown a potential reduction of 50-60% in the overwintering flight the following spring. Removal of fruit prior to codling moth diapause, based on our understanding of photo period-diapause interactions and our empirical data, has shown that significant proportions of the overwintering population can be removed in the previous year. Presently, post-harvest sanitation is achieved by sending a crew immediately after harvest to knock down all pears left in the tree and then picking them up from the ground for juice. The cost effectiveness of this method depends on that year's price for juice and the tree density per acre. In orchards where tree density is too high or when the price for juice is too low growers cannot sustain the additional costs from post-harvest sanitation. Dr. Van Steenwyk has been working on a reduced risk post-harvest treatment of Ethiphon that would accelerate the ripening of pears remaining on the tree after harvest making them unsuitable for CM larval survival. The Pear Advisory Board will seek a Section 24-C for post-harvest use of Ethiphon. One key advantage of post-harvest sanitation is the high level of selectivity and ability to prevent outbreaks the next year, if high CM populations are found at harvest.

Safer Chemical Control

Safer chemical controls that appear promising include the general class of insect growth regulators, such as tebufenozide (recently registered in California), spinozad and second and third generation spin-offs from the above mentioned IGRs. Insect growth regulators appear to be able to provide some control of codling moth without disrupting natural enemy activity thus allowing for biological intense pest management. The level of control is dependent on the compound and level of cross-resistance. Insect growth regulators are envisioned as a keystone soft chemical necessary to deal with sporadic outbreaks of codling moth or some secondary pests, e.g., leafrollers, as the transition to pheromone mating disruption for codling moth occurs in pears. This general grouping of insecticides carry the advantage of much greater selectivity; (e.g., the insecticides impact on target pest with minimal effect on non-target species) reduced mammalian toxicity, and increased farm worker safety. Incorporation of these materials into more comprehensive programs minimizes the risk to non-target species and workers, and decreases the potential outbreaks by other pest species by preventing the disruption of the entire system.

Resistance Management under Mating Disruption (MD)

In addition to managing codling moth efficacy, the Randall Island Project was initiated to combat azinphos-methyl resistance and the increasing need to use greater pesticide loads as resistance increased. **Since mating disruption works best when codling moth populations are at low levels it is also important to preserve the chemicals available to bring down populations when needed.** Given that populations that are resistant to azinphos-methyl have been shown to be cross resistant to other organophosphate, carbamates and insect growth regulators, resistance management is an integral component of a mating disruption program.[7]

Based on a 5-orchard contrast in Randall Island, the increase in resistance to azinphos-methyl has been stopped.[4] Partial reversion (15-30%) in resistance has occurred when no organophosphate were applied during the season. The polygenic, semi-recessive resistance state has been associated with a high fitness cost of 50% reduction in egg laying. Reversion to a previous state of susceptibility has occurred in the laboratory in 6-7 generations. However, this reduction was quickly eliminated after a single uniform application of azinphos-methyl. Laboratory and field bioassays indicate that methyl parathion and azinphos-methyl are negatively correlated in their cross resistance. In other words, the higher level of azinphos-methyl resistance found in a codling moth population, the more susceptible the population was to methyl parathion. Use of methyl parathion gave a partial reversion of 50% in resistance. Negatively-correlated cross-resistance chemicals may be used in a combination of strategies that vary in its use in space and time in a larger resistance management effort. Pheromone mating disruption still needs to be kept as the core non-chemical strategy by which reversion is allowed to take place. Newer chemistries with alternative modes of action need to be initially evaluated with laboratory colonies, followed by field bioassays and then ultimately tested for efficacy and resistance management potential under field conditions. It is imperative to understand that codling moth populations need to be maintained at low levels or mating disruption will fail. For this reason it is important to preserve the use of organophosphate insecticides for the purpose of bringing populations down when they creep up. ***Unfortunately, this tactic is no longer available since the cancellation of tree fruit uses of methyl parathion.***

Pear Psylla, *Cacopsylla pyricola*

Pear psylla's status as a major pest of pears is based on its ability to vector a mycoplasma that causes pear decline and to develop resistance to insecticides. Pear decline reduces tree vigor and causes poor fruit set, small fruit size, and tree death. From 1945 to 1990 pear psylla has become resistant to 21 pesticides from four different classes of compounds. In addition pear psylla injects a toxin into the tree tissue as it feeds causing blackening and burning of the foliage. Also, honeydew produced by psylla feeding runs off and drips onto the fruit. A black sooty fungus grows on the honeydew, russeting the skin which causes the fruit to be downgraded. From a psylla management point of view, softer programs such as codling moth mating disruption afford better control of psylla than organophosphate programs that disturb the predator balance.

The present management of psylla relies on dormant oil sprays and one pyrethroid spray at delayed dormant timing if monitoring (beating tray samples) indicates a need for an additional pyrethroid application. Oil is used during the growing season coupled with abamectin, a microbial by-product and postharvest clean up oil sprays. One of the biggest benefits of implementing the codling moth mating disruption program is to take advantage of the increasing diversity of natural enemies in orchards not regularly treated with organophosphates.

Monitoring: Pear psylla adults are monitored by beating tray sampling or presence/absence sampling of the top shoots of pear trees.

Chemical Control

- Agri-Mek *Avermectin* - (0.15#AI/gallon) 28 day PHI - Used on 92% of the acreage in 1998. One application. Applied at 20oz/acre after petal fall. This is the material of choice for pear psylla control due to efficacy and because it also controls spider mites.

- Asana XL *Esfenvalerate* - (0.66#AI/gallon) 28 day PHI Used on 90% of the acreage in 1998. One application at a maximum of 19oz/acre. Applied at delayed dormant to white bud stage only; however, in any event before egg laying. After dormant oil spray and before bud-break, growers will take beating-try samples and if overwintering adult populations are relatively high, a treatment will be applied.

- Ambush *Permethrin* - (2#/gallon EC) Dormant and pre-bloom applications only. Used on lessthan 1% of the acreage in 1998. 12.8oz to 25.6oz per application applied/acre. Do not exceed 0.8#AI/acre/year. Ambush is perhaps as efficacious as Asana; however, it can be very disruptive to mite predators (causing explosive mite populations later in the season) which is the reason for its limited use.

- Mytac *Amitraz* - (50% wettable powder) 14 day PHI. Used on less than 1% of the acreage in 1998, which was an above average rainfall year. Used primarily in wet (high rainfall) years where growers cannot apply a dormant oil or delayed dormant application of Asana because the ground is too wet for ground application equipment. By the time these orchards become dry enough for ground application equipment, egg laying and hatch have already occurred requiring drastic measures to suppress the population to manageable levels. Disruptive to natural predators.

- Horticultural Oils - In 1995 100% of the pear acreage was treated at least 3-times. Oil has a smothering effect on insects. Used in dormant applications as well as preharvest and postharvest. In dormant applications rates are 15-20 gallons/acre. In-season applications rates are 4-6 gallons/acre depending on the viscosity of the oil.

Mites:

European Red Mite, *Panonychus ulmi*
Twospotted Spider Mite, *Tetranychus urtecae*
Pacific Spider Mite,*Tetranychus pacificus*

Mites in pears are tolerated at very low numbers. Feeding by 2 to 3 spider mites per leaf causes a characteristic blackening of the leaves. High mite population causes defoliation especially in hot weather. Defoliation can reduce fruit size and causes the trees to bloom in the fall, thus severely reducing the following year's crop. The threshold for economical damage is 2 mites per leaf.[10]

One control program relies on dormant and summer oil sprays, biological control by natural enemies and use of in-season abamectin as needed, and in some years a treatment using a selective ovicidal acaricide. As with psylla, organophosphate use tends to exacerbate mite outbreaks. Mite problems have historically been more severe in the coastal pear regions than in the Sacramento delta. The Mendocino areawide project has demonstrated that reducing organophosphate use eliminates the need for post-harvest cleanup miticide sprays and reduces the amount of abamectin needed preharvest. Historically it was believed that the predator mite Metaseiulus occidentalis was responsible for controlling mite populations. Recent research in the Pacific Northwest and California has shown that it is a complex of natural enemies that provide effective biological control of mites.[6] The variance in control seems to depend on specific natural enemies, fauna, surrounding vegetation in individual orchards, the initial spider mite populations and weather conditions. Hot weather favors spider mite population build-up so that, even in the absence of organophosphate use, spider mite control measures are needed given the low threshold of associated damage. California needs to develop a database to document changes in predator fauna over time and their ability to regulate secondary pest outbreaks after the removal of the majority of broad spectrum insecticide usage. Being able to control mites with oil sprays and reserving the use of the abamectin when needed will preserve this selective material. Low levels of spider mite resistance to abamectin has been documented in both the coastal and the delta pear regions in 1997.[4,6] Resistance in spider mites in pears during the mid-1980s presented a severe problem to growers with ever increasing rates and number of applications.

Chemical Controls

- Agri-Mek *Avermectin* - (0.15#AI/gallon) 28 day PHI Used on 90% of the pear acreage in 1998. One Application. Applied at 20oz/acre after petal fall. This is the favored miticide material because it also controls pear psylla. Some low level mite resistance has been documented.[4,6]

- Apollo *Clofentezine* - (1#AI/quart) 21 days PHI. Used on 21% of the pear acreage was treated in 1998. One application. Applied at 4-8oz/acre. This product is an ovicide and should be applied at the first sign of mite activity. Unfortunately, the mite threshold for pears is so low that the "first sign of mite activity" may produce economic damage. Thus, the pesticide is sometimes applied well in advance of "mite activity" whether it is eventually needed or not.

- Savey *Hexythiazox* - (50%WP) 28 days PHI. Apply only once per season. Ovicide. 1.5% of the acreage was treated in 1998

- Horticultural Oils - Dormant rates are 15-20gallons/acre and inseason rates are 4-6 gallons/acre.Used in dormant, pre and post harvest applications. Dormant oil applications help to control overwintering European Red mite populations. Spring and summer applications smother eggs and young developing mites.

Leafroller

Two leafroller species are occasional pests in pear orchards, the oblique-banded leafroller (OBLR) and the fruit-tree leafroller. Of these two species, the oblique-banded leafroller is of greater concern because it has two generations a year and the second-generation causes damage just before harvest. Larvae of the first generation feed in early spring primarily on leaves, but occasionally feed on flower buds, blossoms and young fruit when the leaves are in close proximity. When they feed on young fruit, they cause deep depressions that become rough and russetted by harvest. The second or summer generation causes extensive superficial skin feeding damage when insects feed between two pears in a cluster. Fruit-tree leafroller only causes the early spring damage.[6]

Chemical Controls

- Lorsban-4E *Chlorpyrifos* - (4#/gallon) Dormant and delayed dormant application only. 1.5% of the acreage was treated in 1998. Rate is a minimum 11/2 pint/acre or ½ to 1pint/100gallons of water. The delayed dormant application is only efficacious for the fruit-tree leaf roller and only the first generation of OBLR.

- Organophosphate insecticides used for codling moth control gives background control of leafrollers. In recent years, there have been reports of sporadic poor leafroller control both in orchards under conventional control with organophosphate sprays and in orchards under mating disruption. Problems in conventional orchards may be due to poor timing or coverage or a decreased susceptibility to these insecticides. In orchards under mating disruption leafroller out-breaks have been more severe in the north coast and Lake County than in the Sacramento Delta pear growing district. Although they are becoming more prevalent in long term (4-5years) pheromone mating disrupted orchards in the Sacramento Delta. In the north coast district natural control is not always sufficient to keep leafroller populations in check in the absence of organophosphate use.

Biological Controls

- DiPel DF *Bacillus thuringiensis, subsp. kurstaki (Bt)* (14.5) billion International units/pound) Rates are ½ to 2#/acre. In 1998 Bt was used on 12% of the pear acreage. Bt is presently the only soft control alternative for leafroller control. Bt effectively controls the first leafroller larvae instar before they roll the leaves extensively. Two to three treatments may be required for each generation. The most effective control is early in the spring targeted at the first generation larvae. Since Bt needs to be ingested it is important to apply it when weather forecasts predict 3 to 4 days of warm, dry weather. Larvae are more active and feed more in warm weather than in cooler or rainy weather. In very rainy springs these propitious weather conditions do not occur for proper control with Bt.

OTHER ISSUES

Development of a soft program to deal with leafroller outbreaks may prove critical in pheromone mating disrupted orchards. Research is being conducted on the use of pheromones for leafroller control but results have been mixed. Development of soft insecticide programs, such as insect growth regulators, may provide an interim solution until pheromone mating disruption of leafrollers comes into place. IGRs are widely used in European pear production with great safety and success. As yet, no IGRs are registered for pears in California or throughout the US.

SECONDARY PESTS

Plant Bugs:
Consperse Stink Bug, *Euschistus conspersus*
Lygus Bugs,*Lygus hesperus*

Removal of broad-spectrum insecticides result in outbreaks of some pestiferous species previously suppressed through the use of broad-spectrum neurotoxins. Experiences with mating disruption in the Randall Island pheromone project discovered increased problems with rust mites and lygus bugs and in the Mendocino project increased problems with leafroller and boxelder bug in selective areas. In addition, outbreaks of leafhoppers or pear blister mite have been associated historically with organic or minimal insecticide programs. The frequency and severity of other secondary pests is expected to be highly site-dependent and specific.

Chemical Controls for Plant Bugs

- Dimethoate (several formulations) - Used on less than 1% of the acreage in 1998 primarily for the control of the plant bugs: stinkbugs, boxelder bugs and lygus bugs. Although labeled as a miticide, this product is disruptive to mite predators.

- Carzol *formetanate hydrochloride* - (92% by weight) 7 days PHI Used at the rate of 4oz/100gallons of water. Less than .1% of the acreage was treated in 1998. Although, this product is labeled for pear rust mite, it is used for spot-treatment of plant bug infestations.

Pearleaf Blister Mite,*Phytoptus pyri*
Pear Rust Mite, *Epitrimerus*
San Jose Scale, *Quadraspidiotus perniciosus*

Chemical Controls[10]

- Liquid Lime Sulfur at 5 gallons/100 gallons of water in October or November will control Paearleaf Blister Mite and Pear Rust Mite. Care must be taken to maintain thorough coverage. Additionally, applications should not be too early in the fall (hot days in October) or too late in November. Hot weather in early October may cause bud burn and too late an application may see the adult mites overwintering under the bud scales where efficacy is difficult to obtain.

- Wettable sulfur at 5#/acre in the finger stage (pre-bloom) can also reduce these mite populations. 136,553#s of all types of sulfur were used in pear orchards in1998[11] for both insect and decease control.
- Petroleum Oils There were 1,611,570#s of horticultural oils used in on 60,130 acres of pears with 1,778 applications in 1998.[11]. The dormant application or dormant oil spray is the most efficacious to San Jose Scale and many other overwintering pear insects. Thorough coverage is important for scale efficacy. If a dormant spray is not applied, it is important to

monitor for San Jose Scale using pheromone traps and degree-days in the spring. Timing of San Jose Scale sprays may not be the same as codling moth sprays.[10]

DISEASE CONTROL

Pear Scab, *Venturia pirina*

Pear scab occurs most frequently in the North Coast and Sierra Foothill growing areas where spring rainfall is abundant. Scab symptoms first appear as velvety black spots on young fruit. Infected fruit usually drop; if not, the spots turn into brown, scabby lesions and the fruit becomes deformed as the season progresses. These deformities render the pear useless for commercial purposes. If the fungus continues to develop, the initial fruit lesions produce spores that cause secondary infections or"pinpoint scab".

Pear scab fungi primarily overwinters in infected leaves on the orchard floor; although, in severe infections, twig lesions can be a source of infection. During fall and winter, flask-shaped structures (pseudothecia) project through the top of the leaf and look like small black bulges. Primary inoculum in the spring is from ascospores, which are born in asci or sacs which reside in pseudothecia. In spring, when trees are in the green-tip stage, ascospores begin to mature. Spring rains cause mature ascospores to be forcibly discharged from the pseudothecia.

These primary spores can be carried long distances by air currents to flowers, leaves or young fruit. If the surface of the plant part remains wet and temperatures are suitable, the spores germinate and penetrate the cuticle and outer cells of the plant part, causing primary infection. Primary spores continue to mature in the pseudothecia for several weeks and are released whenever wet conditions occur.

Following infection of flowers, leaves and fruit, the fungus grows beneath the cuticle and eventually ruptures it and forms dark olive green lesions. Masses of secondary spores are produced within these lesions and become detached during rain. Water splashes these spores and any spores that land on fruit or leaves cause secondary infections. Once the fungus is established within the plant, free moisture is no longer required for its continued growth.

For scab infections to occur, three conditions must be met: mature spores must be present, the fruit or foliage must be wet for a specific length of time and temperatures must be within a certain range. The "Mills Chart", named for Dr. W. D. Mills, details the length of time that trees must remain wet, depending on the average temperature, for infections to occur in spring.[10] Further, after primary infection is established and secondary spores are present, hours for re-infestation are only two-thirds of the figures shown in the Mills Chart. Spotts and Cervantes (1994) developed, under Oregon weather conditions, a model to correlate ascospore maturity with environmental conditions during the spring when ascospore discharge occurs.

Fungicides useful for scab control have protectant and/or eradicant activity. To be effective, protectant fungicides (i.e.; liquid lime sulfur, wettable sulfur, Captan, Mancozeb and Ziram) must be present before spores germinate and penetrate the plant surface. To ensure coverage of newly exposed growth, a protectant is applied before an infection period begins and repeat applications every other row at 5-10 day intervals are applied so long as weather conditions are propitious for infection. Eradicant fungicides (i.e., triflumizole) are systemic and are translocated within the host tissue. They can kill the scab fungus up to a certain length of time after infection occurs. This is called the kickback period.

University of California IPM management guidelines rely on monitoring infection periods (Mills Chart) daily to insure coverage of newly exposed growth as long as rains or wet conditions (fog) occur. In addition, these guidelines rely on both the protectant and eradicant qualities of fungicides. UC IPM guidelines recommend beginning the scab season using fungicides as protectants. After initial infection periods, fungicides which are eradicants are important for scab control because some measure of infection may have already taken place and grower application time is reduced due to the shorter time required for secondary infection.

Post-harvest cleanup guidelines advise fall foliar applications of urea or lime sulfur to reduce primary spores the following spring. Urea speeds leaf decay, thus depriving the pseudothecia of a winter host. Lime sulfur will actually kill the spores on contact.

Pear scab monitoring techniques need to be improved to better reflect the regional differences in weather in different pear growing areas. The original "Mills Chart" was developed at Cornell University for apple scab. Although apple scab is a similar organism, it is unclear whether the Mills Chart actually predicts all pear scab conditions. In conjunction with improved scab condition monitoring techniques, some measure of how long pseudothecia release ascospores needs to be developed to determine if the Spotts and Cervantes (Oregon State University) model for asci maturity is accurate and useful for California conditions. This applies to twig lesions as well, which release the much harder to find conidia. A measure of the timing and longevity of these spore releases would help in spray timing, thus offering the potential for reduced spray applications. Research to develop a model was started in 1997 with funding from the pear industry. So far leaf examination revealed that asci matured in California is earlier than predicted by the Spotts and Cervantes model and they exhausted their spores earlier in the season.

Chemical Controls

Control Options	**Has Resistance Developed?**
Benlate - *Benomyl* (50%WP) 14 days PHI; Not more than 5#s/year; 12-24oz/acre/app. '98 use: 12,249#s on 23,227 acres	Yes. Data from Dr. Doug Gubler [12]
Procure - *triflumizole* (50-%WS) 14 days PHI; Not more than 63oz/year; 8-16oz/acre/app. *'98 use: 2935#s on 9,314 acres*	No. Has high resistance potential[12]
Rubigan - *fenorimol* 30 days PHI; Not more than 84oz/acre/year; 8-12oz/acre/app. '98 use: 1,557#s on 14,574 acres	No. Has high resistance potential[12]
Vangard - *cyprodonil* New Registration '98 use: 0.66# on 79 acres	New registration; resistance potential unknown
Dithane M-45 - *Mancozeb (EBDC)* 77 days PHI; Not more than 21#s/year; 3#s/acre/application '98 use: 90,749#s on 35,369 acres	No. Has low resistance potential
Ziram 76DF - *Ziram (DMDC)* 5 day PHI; Not more than 32#s/year; 6-8#s/acre/app. '98 use: 87,763#s on 21,416 acres	No. Has low resistance potential
Sulfur '98 use: 136,553#s on 13,670 acres	No. Has low resistance potential

The are two new pear scab registrations for the 2000 crop year which should reduce the use of Benomyl significantly. They are Syllet (dodine) and a reduced risk classified product called Flint. Both of these fungicides have dissimilar modes of action from each other and from the fungicides listed above. Of course, the driving force for increased use of fungicides is the weather (wet springs).

Cultural Controls

Fall foliar applications of urea and/or liquid lime sulfur have proved useful in reducing primary spores the following spring.

- Urea helps speed leaf decay in the winter, thus taking away the organism's food supply. A minimum of 50 pounds of low-biuret urea in 125 gallons of water/acre is required. Urea applications will not kill scab twig lesions.
- Liquid lime sulfur applied 15 to 24 gallons per acre in the fall or in the delayed dormant period has been observed to kill scab twig lesions.[12]
- Copper sprays have been used in delayed dormant or bud break stage as a protectant. However, after fruit formation, copper heavily russets the smooth skinned Bartlett pear. This renders it useless for the fresh market.

Biological Controls

There are no biological controls.

Pest Resistance

Dr. Doug Gubler, UC Davis, and his assistant Ken Dell have documented *Benomyl* resistance in approximately 10% of the isolates collected from Mendocino and Lake Counties in 1998.

Resistance management in the case of high-risk fungicides would consist of alternating applications of fungicides with different modes of action or with low resistance risk protectants such as Dithane or Ziram.

Fire Blight, *Erwinia amylovora*

Fire Blight, is a severe bacterial disease problem in California pears. In spring, disease symptoms can appear as soon as trees begin active growth. Overwintering cankers exude a watery, light tan bacterial ooze that turns dark after exposure to air and causes leaves dark streaks on branches and trunks.

Flowers are usually infected first in the spring. Infected flowers and flower stems wilt and turn dark. Blight infections move into twigs and branches from infected blossom clusters. When they do, infected leaves and small shoots wilt and eventually turn black. When blight bacteria spread from blossoms into wood, the newly infected wood underneath the bark has pink to orangish red streaks. As the canker expands, the infected wood dies, turns brown, and dries out.

Late bloom (rat-tail bloom) or shoot infections in April, May and June during favorable fire blight weather can cause losses of infected pear limbs and trees. Cankers can girdle and kill entire branches or trees in a few weeks. The closer the canker is to the trunk or rootstock (bud union), the greater the potential for damage or loss of the tree.

Fire blight bacteria overwinter in cankers. In spring, when the weather is sufficiently warm and moist and trees are actively growing, bacteria multiply in diseased tissues. A light brown liquid, consisting of bacterial cells in slime, oozes from the branch or twig surfaces. These bacterial cells are transmitted to nearby blossoms or succulent growing shoots by hail, rain, insects or wind. The bacterial cells colonize the flower's stigmas and under favorable conditions, the colony grows rapidly. Ideal conditions for infection, disease development, and spread are rainy or humid weather with daytime temperatures in the range of 75° to 85° F, especially when night temperatures are above 55° F.

Bees and other insects transmit the bacteria from the stigmas of infected blossoms to healthy blossoms. During a fire blight epidemic in an orchard, many insect species are attracted to the bacterial ooze on infected trees and help spread the pathogen.

Once fire blight bacteria enter the blossoms, they may cause only a localized infection and eventually die, or they may move into the twigs and branches. Fire blight bacteria that survive generally do not move through the wood uniformly but invade healthy wood by moving in narrow paths, 1/2 to 1-1/2 inches wide in the outer bark, ahead of the main infection. These long narrow infections (stringers) may extend 2 to 3 feet beyond the edge of the main infection or canker. Removing bark from the stringer shows the diseased tissue closest to the main canker is brown. Further along the stringer, the tissue turns red and then appears as a red flecking. At the front of the infection, the tissue may appear healthy but it is actually infected 12 inches or more beyond the visible infection.

Removing infected wood is essential to controlling fire blight in pear orchards. One active overwintering canker located high in a tree can infect many surrounding trees. A few overwintering cankers per acre can provide enough inoculum to render ineffective a preventative spring spray program. Thus, growers employ teams of blight-cutters during spring and fall to remove cankers that have overwintered as well as new blight infections.

Blossom applications of copper materials or antibiotics such as streptomycin or terramycin are used in pears to reduce the spread of fire blight bacteria. Pest control advisors monitor fire blight bacteria populations in pear blossoms as well as average daily temperatures or degree-hours to schedule fire blight sprays.

Anitbiotic Control

- Mycoshield *Ocytetracycline* - (17% oxytet.) 60 days PHI. 1998 use was 14,383#s on 65,263 acres. Rate per acre: maintaining 160-200ppm is critical for efficacy. 200ppm would be 1#/100gallons of water. This product is rarely applied at more than 100gallons/acre because of the increased cost at higher gallonages. Mycoshield is the antibiotic of choice for fire blight control.
- Agri-mycin 17 *Streptomycin Sulfate* (17% Streptomycin) 30 day PHI. 1998 use was 6,134#s on 64,895 acres. Rate is 28.8oz/acre. Dr. Steve Lindow UC Berkeley, has documented resistance in some orchards in 1997; however, this resistance is no greater than it was a 20 years ago.
- Copper Compounds *copper hydroxide, copper oxide & copper oxychloride sulfate* - No PHI. Use in 1998: copper hydroxide - 12,447#s on 6,144 acres; copper oxide - 53#s on 61 acres; copper oxychloride sulfate (6% dust) - 1114#s on 5,737 acres. Wettable copper compounds russet the smooth skinned Bartlett pear. Thus, they are not used during or after bloom. Growers use copper dust in rotation with the antibiotics as a resistance management tool.

Biological Control

A naturally occurring organism, *Pseudomonas fluorescens* has recently been registered as BLIGHT BAN A-506 which acts as a competitive exclusion agent. The integration of Blight Ban into blight control programs shows promise for reductions in the use of antibiotics. In field trials with A-506 the frequency of antibiotic sprays was reduced by about 50% of the normal antibiotic fire blight spray program. Do not tank-mix Blight Ban A-506 with Mycoshield.

Mycoshield can be applied after the establishment of the bacteria in the orchard. Blight Ban A-506 is incompatible with copper compounds.

Again, weather conditions play a vital role in the timing of spray applications. Research into the level of blight bacteria content of an orchard in conjunction with improved knowledge of monitoring of temperature and humidity thresholds offers the potential for reduced antibiotic applications.

WEED CONTROL

Commercially adopted methods for economically controlling weeds in California pear orchards include mowing, cultivation, the use of selected cover crops and herbicides. Weed control is an integral component within a successful and economically viable IPM program for commercial pear production, and is not simply a means for cosmetic enhancement. Poorly managed weed growth is detrimental to all commercial tree fruits -including pears for a number of economic reasons: 1) Weeds compete directly with young and old pear trees alike for water and nutrients; 2) weedy orchards have higher humidity and slower drying conditions, creating an environment ideal for the development of diseases such as pear scab and crown rot; 3) dense weed stands lower orchard temperatures, increasing the risk of frost damage in the spring; 4) weeds are also excellent hosts for spider mites and true bugs providing a ready access to the tree; and 5) weedy orchards provide a habitat ideal for detrimental rodents.

Mowing and Cultivation

Weeds in established orchards can be managed by cultivation, mowing, or a combination of both. Cultivation does incorporate a desired amount of organic matter back into the upper soil profile. Cultivation and mowing is primarily used in the alleys. Because cultivation near the tree trunks can cause increased soil compaction, physical damage to the tree by cutting feeder roots and trunk increasing the chance for disease invasion, and unsatisfactory weed control, herbicides are frequently applied in a strip treatment down the tree row.

Mechanical mowing is used primarily during the spring and summer months in irrigated orchards. Mowing is commonly used in most pear orchards because it tends to be less disruptive to the soil and trees, and also tends to be more economical than cultivation. Chemical mowing, the use of varying rates of glyphosate to control existing ground cover, helps conserve soil-stored water, as well as provide mulch which further helps to conserve water. Soil compaction is minimized as well.

As cultural control technology becomes increasingly more sophisticated in the future, new feats of engineering may allow production agriculture the opportunity to further reduce their dependency on chemical weed control.

Selective Cover Crops

Cover crops for pears, other than a composition of general weed species, have been researched extensively in the last few years in California, by University of California Cooperative Extension, to select specific annual and perennial cover crop species that provide the desired characteristics, unlike those of a regular weed ground cover.

Cover crops when properly managed allow for good water penetration while reducing erosion, tend to have higher populations of beneficial insects and mites than clean-cultivated orchards, provide excellent competition for weeds, and in the case of leguminous cover crops such as clovers, provide a certain level of beneficial nitrogen to the trees. The majority of pear growers in California are currently employing some form of general ground cover in their orchards, but subsequent research will be required to identify selective cover crop species that are 1) economically feasible for a grower to plant, and 2) that will perform well under less optimal conditions.

In 1993, UC research discovered that the plant species composition of pear orchard floors, which include such weeds as annual and perennial ryegrass, are supporting high populations of bacteria that were conducive to both severe fruit russeting and frost damage. Researchers identified a number of specific cover crop species that have been shown to harbor considerably lower populations of russeting bacteria, while maintaining all the favorable characteristics of a perennial cover crop. We need to continue research into cover crops selection and supplemental fertilization needs. We also need to improve education and implementation of commercially select cover crops for economical weed management.[14]

Chemical Control (Herbicides)

Chemical control is the most frequently used method for controlling weeds in the tree rows. Keeping weeds away from tree trunks without injuring trees is very difficult with mowing and cultivation. Herbicides provide pear growers with the necessary flexibility to economically control/suppress weed growth where needed in a timely fashion.

The California pear industry has been conservative and conscientious in its use of herbicides for weed management. Of the limited number of herbicides currently registered for commercial use in pear orchards, the pear industry utilizes only a small percentage of them on a regular basis. Preemergence herbicides can control weeds from several weeks up to a year, depending on yearly rainfall, the solubility of the material, soil properties, frequency and method of irrigation, weed species, and dosage applied. Preemergence herbicides control weed seedlings as they germinate and must be selected on the basis of the weed species found in the orchard. Splitting a preemergence treatment into two applications can prolong control, particularly in areas with heavy rainfall, in orchards with sandy soils, or in orchards with a heavy growth of summer annuals.

Postemergence herbicides are applied primarily to spot treat perennials in the tree row when monitoring indicates a need. Rate and use depend upon the weed species present and the size of the weeds. Glyphosate (Roundup) is the herbicide used most extensively by the California pear industry, both in terms of total acreage and volume applied. This is because it is economical, broad-spectrum, very efficacious, as well as inherently safe, and it has also incorporated very well with the current and future IPM framework for pears. With herbicide application technology continually advancing, such as with the recent introduction of the Ultra Low Volume technology, pear growers are now able to apply considerably less glyphosate per acre to their orchards and the environment, while still achieving the same degree of efficacy as in the past.

Monitoring is essential for choosing the correct preemergence herbicides and deciding whether a postemergence herbicide is needed and which one to use. Records are important to weed management. Weed survey information collected over several years is valuable in identifying changes in weed populations and in planning an IPM program.

New or enhanced herbicidal spray application technology, ultimately improve overall safety, economics (time and product used), efficiency, and efficacy of the compound.

Herbicides below are used primarily in the row strip (4' to 6') unless otherwise noted

- Solicam DF *norflurazon* - Preemergence herbicide. (80% dry flowable) Apply 2.5-5#s/acre depending on soil type. 6% of the pear acreage was treated in 1998.

- 2,4-D - Postemergence herbicide. (Several formulations) Apply 1qt-2qt/acre. 20% of the pear acreage was treated in 1998. This is the herbicide of choice for field bindweed which twines itself around solid set sprinklers and renders them inoperable.

- Karmex DF *Diurn* - Preemergence herbicide. (80% dry flowable) Apply 4#s/acre. 15% of the pear acreage was treated in 1998.

- Roundup *glyphosate* - Postemergence Herbicide. 14 day PHI. (4#/gallon AI) Applied to 89% of the pear acreage in 1998. Rate: 12-24oz/acre depending on application equipment.

- Surflan *Oryzalin* - Preemergence herbicide (4#s AI/gallon) Apply 2-6qts./acre. 7% of the pear acreage was treated in 1998. Only pear preemergence herbicide that can safely be applied around one-year old trees.

- Gramoxone *paraquat dichloride* - Postemergence herbicide (2.5#s/gallon) Apply 2-3pints/acre. 48% of the pear acreage was treated in 1998.

- Princep 4L *Simazine* - Preemergence herbicide (4#s/gallon) Apply 2-4qts./acre. 17% of the pear acreage treated in 1998.

Biological Control

Since most weeds tend to be very host specific, there are very few biological control agents commercially available today that are capable of addressing weed control on a broad spectrum basis. Several species of insects have been identified as bio-control agents on certain weed species — Puncture Vine Weevil for example — but the few that exist don't impact the primary weed species that are presently the most noxious and economically detrimental in commercial pear orchards. Biological control of weeds in orchards is limited because the orchard environment is disturbed frequently by cultural operations and agricultural chemicals. Populations of natural enemies of weeds cannot develop high enough levels to control weeds adequately.

NUTRITION

A healthy plant is the baseline defense against insects, mites, nematodes, and pathogens. Integrated pest management treats pests as part of a crop production system that includes not only the crop and its pests, but also the physical and biological environment in which the crop is grown. Current fertilization practices employed by commercial pear growers are designed to provide the necessary requirements for plant growth minimizing runoffs of phosphorus and nitrogen into rivers, lakes and coastal waters. In aquatic ecosystems, over enrichment with nitrogen and phosphorus causes loss of biodiversity in marine and freshwater resources and impairs their use.

Of the three primary elements commonly associated with plant growth (nitrogen, phosphorus, and potassium) nitrogen is the primary nutrient responsible for IPM-related maladies, excluding phytotoxicity. Early UC research has shown that excessive levels of actual nitrogen in the pear tree can result in excessive shoot growth, consequently, resulting in increased susceptibility to the fireblight pathogen. This lush, rapid tissue growth is also conducive to greater infestation levels of pear psylla as well. Since nitrogen has been shown to play less of a role in pears than some of the other elements (zinc, boron, potassium, calcium), nitrogen is used very conservatively in most instances.

Tree fruit growers have a tissue analysis performed each season to better evaluate the complete nutrient composition of their orchards. This analysis provides an accurate picture of what elements are lacking or are in excess within the tree, so that a nutritional recommendation can be made that more closely fits the specific needs of the tree and orchard.

For example, nutritional research recently compiled in 1994 by the University of California, Davis[15], overwhelmingly concluded that the "Bartlett" pear tree is nitrogen tolerant and that the fruit is nitrogen insensitive. This type of data is invaluable to a successful IPM program because it allows pear growers the opportunity to more effectively manage the nutritional needs of their orchards by eliminating unnecessary applications of N which, in turn, dramatically reduces the risk of fire blight and pear psylla, and the eventual need for additional antibiotics and insecticides to control them.

Furthermore, the gradual introduction of select cover crops that supplement the soil with adequate levels of nitrogen, such as the perennial legumes, may provide growers with the opportunity to minimize the need for unnecessary nitrogen applications thus minimizing nonpoint pollution of our streams due to runoff.

VERTEBRATE PESTS

Pocket Gophers, *Thomomys spp.*

Chemical

- Strychnine - 0.5% bait. 2% of the pear acreage treated in 1998. Placed in the burrow_with a mechanical burrow builder or with hand probes. Usually very effective and no secondary wildlife hazards.

Field mice, multiple species

- Zinc phosphide - 0.5% bait. 35% of the acreage was treated in 1995. (5.88#s AI on 98 acres) Applied with a broadcast spreader or by hand around mice burrows.

COMMUNICATION

Communications between growers, PCA's and researchers by fax proved a key to the successful of implemention of areawide projects. Given that reduce risk pest management depends on well informed growers and trained PCAs, increases access to information is imperative. To increase communication, better educate the grower community and provide a mechanism for two-way data transfer, the pear industry created a Home web-page (www.calpear.com). This provides economically feasible, multi-media communications among all stakeholders (growers from within and outside the state of California, researchers, extension staff, and regulatory agencies). With scarce grower resources, tapping into the pest management expertise garnered in other parts of the country and the world makes both good economic and environmental sense. Information developed by the Pear Pest Management Research Fund and the California Pear Advisory Board is posted at the site. The web page also provides links to other pear and pest management sites.

While the pear growing community is computerized to varying extent, the majority of the industry has not yet developed a comfort level with computerized communications to the degree necessary to undertake an industry-wide electronic forum. We will concentrate in increasing growers computer literacy to utilize this medium to its full potential. This will allow for transfer of knowledge and technology and provide a world-wide IPM forum for the growers.

BARRIERS TO ADOPTION

Regulatory and Administrative Barriers

Barriers to the rapid deployment and testing of new pheromone-based products have decreased with recent streamlining of regulatory processes for semio-chemical pesticides using removable technologies. The need to test on large scales under EUP (non crop-destruct) conditions can still be limited by existing acreage limits. Expediting registration of products that either minimize risk or decrease total pesticide output into an agricultural setting need to remain a priority.

Similar logic applies for materials such as insect growth regulators that present similar positive attributes of selectivity and minimized mammalian toxicity. Insect growth regulators also possess the unique ability to integrate well with pheromone-based programs without the loss of selectivity typically associated with many classes of pesticides. Lack of registrations for new, safer compounds not only limits available options and management flexibility for growers, but restricts product competition in the marketplace and keeps control costs artificially high.

Inclusion of resistance management criteria in the review or registration of insecticides would help in developing new management practices. Total pesticide requirements are minimized if resistance levels can be kept below crises proportions.

Economic Barriers

An obstacle that continues to face the large scale implementation and adoption of pheromone mating disruption in pear orchard is the initial higher cost. Current estimates suggest that pheromone mating disruption in CA is $75-100/acre more expensive than full organophosphate programs. The cost of the pheromones dispenser and the labor to put them up is higher than the application of three to five organophosphate cover sprays and orchards under mating disruption require intensive monitoring. However, these analyses are unable to consider the potential benefits of reduced pesticide costs associated with not disrupting an orchard with broad spectrum materials that is seen after one or two years under the program. The inability to include these costs is in part a function of the lack of scientifically acquired data on the potential and costs of secondary pest outbreaks. The differential between the programs is expected to decrease as these types of data become available and are incorporated into cost/benefit analyses.

New technologies for dispensing the pheromones will be on the market in the coming year and yet others are being researched (sprayables and new female attractants). With increased competition among the different manufacturers there is a possibility that the cost might be reduced increasing adoption.

Education

Use of pheromone-based programs for codling moth is a significant departure from use of cover sprays with broad spectrum neurotoxins. Mating disruption is an information-intensive approach that relies heavily on intensive monitoring and the correct interpretation of the data to avoid having losses from unforeseen outbreaks. It also entails changes in timing of applications, labor requirements and their mobilization at key periods in the season, enhanced use of degree-day modeling, and increased necessary vigilance for outbreaks of more rare secondary pests normally not found in OP-dominated systems. Until growers develop confidence and personal experience in theses new technique, they will continue to perceive them as highly risky. This perception sometimes hampers implementation even more than the biological or economical constraints. The currently established base of pest control advisors in California make for a unique environment for alternatives such as pheromone-based programs to be adopted.

In addition, grower education for issues such as regional management of pests and their resistance will remain an ongoing need. Factors that we feel proved key to the success of the Areawide Projects have been the increased share of data amongst growers, the use of electronic data transfer (faxes) for all participants, and the placement of an on-site liaison between the University and growers.

SUMMARY

In the past 10 years the pear industry through its research funding program has supported research into low risk alternatives for pest control and encouraged their adoption. Much of the research that was begun with Pear Pest Management Research Funds later leveraged the support of USDA-ARS, California Department of Pesticide, and EPA-Region 9 funding that enabled the pear growers to increase adoption.

Three key factors have provided the immediate impetus to re-examine pest management in pears based on broad spectrum materials: 1) the development of low, yet significant, levels of resistance in codling moth to azinphos-methyl; 2) the technological breakthroughs in pheromone delivery systems; and 3) an awareness of public and private concerns about food, worker, and environmental safety that are shared by pear growers. The recent development of alternatives to organophosphate-based programs for control of the key pest in pears provides a clear biological pathway to reducing pesticide output into the orchard ecosystem, minimizing farmworker exposure or risk, producing minimal residues on food, and enhancing the use of biological control for secondary or other key pests.

Much has been accomplished since the start of the Randall Island mating disruption project in 1993. There is an increased grower and PCA confidence in this reduced risk management program. Application technology has improved with longer lasting and more reliable pheromone dispensers and more reliable though intensive codling moth monitoring techniques suited to pheromone saturated orchards. To date, the large scale implementation effort has already produced an 75% reduction in organophosphate use in areas under mating disruption. In addition, the projects appear to have allowed for a partial reversion of azinphos-methyl resistance and hopefully a reversal in the increasing spiral of rates and application frequencies. The integration of a new orchard sanitation program, a classical biological control program, an augmentative biological control program, and pheromone mating disruption for codling moth is providing a multi-pronged attack on the main pest in pears with minimal risk.

Given that reduce risk alternatives are based on detailed knowledge of the biology of the pests, intensive monitoring approaches and understanding of the data, grower education and assistance in implementation is an ongoing need. The demonstration of large scale implementation by key growers needs to continue to establish the reliability of the approach to growers, the expansion of the programs to new regions, the ability to include a new generation of selective insecticides (e.g., insect growth regulators) on an as-need basis, and completion of several research questions limiting implementation. The rapid registration of alternative soft materials, e.g., insect growth regulators, for management of secondary pests and codling moth where appropriate is needed. Given the present technology, there is still a need for a limited use of OP insecticides for transition to pheromone-based programs and the occasional use of OPs to lower codling moth populations and maintain these programs. The pear industry is committed to continue research into specific implementation barriers and development of new reduce risk alternatives.

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