The Foundation for a Pest Management Strategic Plan
in
Almond Production

Summary of a Workshop Held December 12, 2002
Modesto, CA

Almond Board of California
California Pest Management Center

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The Work Group:

A workgroup consisting of almond growers, Pest Control Advisors, Farm Advisors, technical experts (entomologists, IPM specialists, and researchers) and members of the Almond Board of California met on December 12, 2002 in Modesto, California. The objective of the meeting was to identify research, regulatory actions and educational efforts necessary to develop a foundation for a pest management strategic plan for almond growers that could lessen or possibly eliminate use of “high risk” pesticides in almond production. The effort and outcome of this group reflects the almond industry’s pro-active efforts to provide comprehensive information on orchard practices, to continue our efforts in environmental stewardship, and to facilitate the exchange of information with our partners in stewardship efforts, including government agencies.

The workgroup collectively identified and prioritized the following critical needs of the almond industry:

Top Research Priorities in the Almond Industry:

- Identify and assess efficacy and most beneficial use patterns of novel reduced risk chemistries/compounds.
- Evaluate emamectin benzoate (Proclaim), diflubenzuron (Dimilin), novaluron (Rimon) and thiacloprid (Alanto/Calypso) for rates, timing, application methods and efficacy for control of Peach twig borer (PTB), Navel orange worm (NOW) and/or San Jose scale (SJS) while considering honeybee toxicity and long-term impact on non-target invertebrates
- Development of Best Management Practices (BMPs) for watershed protection
- Develop economic threshold models and more refined monitoring systems for NOW
- Study methods to improve pheromone mating disruption techniques and cost effectiveness for NOW and PTB
- Develop better sampling methods and economic threshold levels for PTB
- Determine timing of PTB generations in relation to crop susceptibility and harvest (a hull split predictive model).
- Economic threshold studies and monitoring methods for ants.
- Studies to better understand replant disorder, soil biology, resistance to ring nematode and root lesion nematode, and new post-plant nematicidal agents.
- Research possible new pre-emergent herbicides.
- Control of vertebrates, especially in the areas inhabited by endangered species.
- Identify an alternative to methyl bromide for use as a pre-plant fumigant and possible alternatives to phosphine for post-harvest fumigation.

Top Regulatory Priorities for the almond industry:

- Allow for judicious use of OPs, particularly in non-sensitive areas, to prevent major outbreaks of primary secondary pests and exotic pests, while managing resistance.
- Expedite registration of novel reduced risk chemistries/compounds found to be efficacious for navel orangeworm, PTB and SJS control.
- Expedite registration of methoxyfenozide for control of NOW.
- Expedite registrations of methyl bromide alternatives (including iodomethane) and provide relief from Telone restrictions including township caps, surface moisture requirements, and allow higher concentrations of Telone in finer-textured soils.
- Expedite registrations of late season alternative chemistry for disease control and to manage resistance.
- Allow for rodenticide use in crops and clarify label for such use.
- Relief from overly burdensome Endangered Species Act (ESA) requirements.

Top Educational Priorities for the almond industry:

- New pest management tools as they become available.
- Resistance management.
- Monitoring techniques, economic thresholds and proper timing of spray applications.
- Best Management Practices (BMPs) for watershed protection.
- Endangered Species Act (ESA) requirements.
- Ensure sufficient numbers of independent pest control advisors/ extension personnel

Background:

California produces three-quarters of the world's supply of almonds. California farmers are some of the most productive and efficient growers in the world, relying on nearly 30 years of industry-sponsored research totaling an investment of $15 - $20 M. Finely-tuned production, built on the backbone of Integrated Pest Management (IPM) techniques allows California almond growers to produce five times the crop on one-third the acreage of their nearest global competitor, Spain. In California's Central Valley, 535,000 bearing acres are devoted to growing almonds. Over the last several years, an average of 80% of the crop was exported to over 90 different countries. In 2002, almonds were the top ranking U.S. horticultural export, far outranking exports of wine, oranges, apples, grapes and raisins. Total farm gate value is around $1 billion.

Approximately 30 varieties of almonds are grown commercially in California with Nonpareil, a soft-shell variety, accounting for about 40-45% of the production. A majority of the commercial cultivars are self-unfruitful, thus typically 3 different varieties of almond are grown in an orchard to allow cross-pollination by insects, primarily honeybees. Honeybees in overwintered colonies are the only pollinators currently available in adequate numbers to service the almond industry.

Selected varieties are grafted onto rootstocks, usually Nemaguard peach rootstocks, although less common rootstocks include various peach/almond hybrids, standard peach, plum, and rarely almond itself. Irrigation is essential to successful almond production in all parts of the state. Orchard floor management is important to the grower as the crop is swept into windrows after being knocked off the trees. The orchard floor must be level and clean of weeds and debris at this time.

Numerous insect and mite species occur in and around almond orchards throughout the entire state. The major pests are present in all almond-growing areas of the state and occur at damaging levels most seasons. Other pests are either sporadic in occurrence or the distribution and damage potential are more restricted. Almond pests damage the crop in a number of ways. They feed directly on the kernels, create openings for fungal infestations (e.g., aflatoxin-producing *Aspergillis* spp.), damage growing shoots, kill branches, fruit spurs and scaffolds, defoliate trees, weaken trees and limbs by boring into the wood, cause embryo abortion, and kill whole trees by feeding on the roots.

Brown rot, anthracnose, jacket rot/green fruit rot, shot hole, scab, leaf blight, *Alternaria* leaf spot, rust, and hull rot are the most common and devastating fungal diseases of almond. Wood decay disorders also commonly occur in older orchards. Silver leaf disease had recent outbreaks in Stanislaus and Merced Co. *Phomopsis* fruit rot and *Ceratocystis* and *Botryosphaeria* cankers are less common. *Phytophthora* root rot and *Armillaria* root rot can be problems in wet years when flooding occurs or in specific regions with a history of the disease, respectively. Other diseases such as aerial *Phytophthora* occasionally occur in high rainfall or flood conditions. *Verticillium* wilt generally occurs in crop rotations where high populations of the fungus exist. Bacterial diseases such as almond leaf scorch, crown gall, and bacterial blast or canker are also perennial problems in California. Diseases absent or rarely found in California include: leaf curl, *Leucostoma* canker, red leaf blotch, *Rosellinia* root rot, powdery mildew, cotton root rot, and bacterial hyperplastic canker. Phytoplasma (almond brown line and decline - peach yellow leaf roll) and virus diseases (calico, peach mosaic, and peach yellow bud mosaic) have also been reported in California. Numerous other virus diseases have been reported worldwide.

In young orchards, weeds compete directly for water and nutrients necessary for growth. In mature orchards, controlling weeds minimizes competition for these resources; ensures efficient management, cultural practices, and harvest; reduces frost hazard in early spring; prevents weeds from flowering at the time trees bloom, thus minimizing competition for pollinators; and facilitates efficient use of low-volume emitters. No system of weed control is ideal in all circumstances. Various combinations of pre- and post-emergence herbicides and mechanical operations are used for weed control during the season and vary between orchards. Weed control measures are based primarily on economic concerns, efficacy of the various chemical and non-chemical options, weeds present, and availability of labor and equipment.

Several species of plant parasitic nematodes negatively impact almond production at sites throughout California. In a 1987 California survey, incidence of almond orchard infestation with plant parasitic nematodes varied widely (roughly, from less than 20% to more than 50%) and depended on region, soil type, and nematode species. Nematode pests damage trees by feeding on the roots. The impact of the root damage is greatest for young trees, particularly in the first year after planting. Stress induced by ring nematode can predispose almond trees to bacterial canker disease on sandy soils. None of the almond rootstocks is resistant to all of the damaging nematode species, although Nemaguard, Nemaguard x almond hybrids, and Marianna 2624 stocks are resistant to root knot nematodes. Additional control of nematodes is achieved principally through pre-plant soil fumigation.

Pest control methods involve the use of dormant and/or in-season sprays. Dietary risk from pesticide residues is extremely low because the almond kernel, the actual component consumed, lies within a protective shell and within a hull.

Organophosphates (OPs) are an important class of pesticides used in almond orchards in California. These pesticides are often broad spectrum in that they control many of the key insect pests that appear every year, some of the sporadic pests, and other historical injurious species that seldom appear today. Frequently a single application is used to control two or more key pests simultaneously. The organophosphates are economical; pest resistance to the OPs is not widespread; based on the timing of application, they may not harm beneficials and are a part of current IPM programs. They are also less toxic to fish than some of the registered alternatives.

EPA is in the process of re-registering pesticides under the requirements of the Food Quality Protection Act (FQPA) and FIFRA. The Agency is examining dietary, ecological, residential, and occupational risks posed by all pesticides. EPA=s regulatory focus on some of the widely used pesticides has created uncertainty as to their future availability. At some point the EPA may propose to modify or cancel some or all uses of these "high risk" pesticides for almonds. To fill data gaps EPA requires registrants to complete regulatory studies that may result in some companies voluntarily canceling registrations for almonds. In addition, environmental groups are raising public awareness through campaigns addressing pesticide use and environmental impacts.

The concerns regarding the use crop protection tools are just some of the critical issues growers must face. Agriculture needs to respond in a proactive manner. It cannot accept a passive role and allow the EPA and other groups to determine the future of pest management. The alternative is to be proactive, develop Pest Management Strategic Plans that reflect the needs of growers, and demonstrate to EPA and others what steps and measures agriculture can take to reduce and/or eliminate pesticide use, risks, and residues.

The USDA, EPA, land-grant universities and almond industry need to proactively identify regulatory, research, and educational needs for replacing the "high risk" pesticides with cost-effective alternatives, if necessary, as a result of EPA=s implementation of the FQPA. The development of pest management strategic plans, priorities, and specific pest-by-pest critical needs are the goals of this document.

Several thoughts were key to the process of updating this Pest Management Strategic Plan. First and foremost was the welfare of the farmer; any pest management strategic plan developed had to allow for continued profitability for growers by providing cost-effective alternative pest management tools. Geographical regions had to be considered when developing transition strategies due to differences in production practices, pest complexes and pressures, environmental conditions, crop varieties, and marketing opportunities. The big picture needed to be considered. A one-chemical-at-a-time process would not work. The workgroup believed that discussing the issues in individual commodity (almond) and specific pests would be the most effective way to develop a transition strategy. The group would identify gaps and needs that would become the basis for the pest management strategic plan. This plan would identify needs in the areas of research, regulatory actions, and educational programs for almond growers to attempt to move away from "high risk" pesticides.

General Conclusions of the Workgroup:

Almond operations range in size from 5 to 30,000 acres

- Almond acreage is increasing.
- Orchards tend to be larger in the south and during intensive management times size can lead to:
  - Equipment shortages
  - Labor shortages
- Access of shakers into orchards for winter sanitation practices can be limited in the north due to wet soils.
- 75% - 85% of the almond acres have a licensed Pest Control Advisor to assist the grower in making pest management decisions.
- Regardless of orchard size, grower and consumer education is of utmost importance.
- A majority of the Almond Board production research budget is devoted to IPM issues.
- Almond growers have used IPM programs since the early 1960s and have continued to refine and improve the programs through research and education programs.
- The Almond Board supports demonstration and comparative research plots throughout the growing region.
- The major almond pests include ants, mites, navel orangeworm, peach twig borer, San Jose scale, brown rot, shothole, anthracnose, scab, alternaria, nutsedges, purslane, perennial grasses, fleabane, ring, lesion and rootknot nematodes, ground squirrels, pocket gophers, and deer mice.

2. Within California, regional differences occur including:

- Pest complexes.
- Pesticide registration differences.
- Pesticide efficacy differences.
- Varietal differences.
- Production practices
- Climatic differences:
  - Dry in the southern production region.
  - Wetter in the northern regions.
  - Chilling and frost differences moving from north to south.

3. Regional pesticide application differences occur:

- Timing of dormant oils can range from December through January.
- Bloom-time sprays can range from February through March.
  - Timing of dormant oils and bloom-time sprays occurs earlier in southern production regions.
  - In the north, bloom sprays timed more to stage of bloom (variety dependent) rather than a more unified timing as in the southern regions.
  - In the north there is a greater chance of rain during bloom, making timing of bloom sprays more difficult.

- Due to wet, heavier soils aerial applications are more common in the northern regions.

4. Good dormant sprays and *Bt* bloom sprays can be important – may reduce the need for post-bloom sprays.
5. Loss of broad-spectrum pesticides has resulted in a different pest management regime.
   - Decreased use of these broad-spectrum pesticides sometimes results in secondary pest outbreaks previously found rarely in almond orchards.

General Suggestions for a "Pest Management Strategic Plan":

- Provide for continued joint EPA and California Department of Pesticide Regulation (DPR) reviews for Section 3 registrations.
- Redefine Experimental Use Permit (EUP) process for benign products, acre limitations and crop destruct restrictions.
- Harmonization University of California (UC), USDA, and EPA efforts particularly in communicating of research needs and results.
- Facilitate UC Cooperative Extension Advisors' and Specialists' strengths in transmitting information between academia and growers.
- Utilize advantageous media capabilities of USDA to facilitate transfer of information and technologies to growers.
- Pursue USDA research for demonstration projects.
- Improve California allocation of USDA-Extension funding so that California farmers receive allocations on par with smaller southern states.
- Explore pursuing IR-4 petitions via a "nut crop" grouping and form alliances with other nut crops to ensure our high priority needs are being met.
- Shorten the Section 18 approval process to prevent the granting of late, useless Section 18s.
- Ensure funding for extension specialists and others to advise growers in IPM practices.

The remainder of this document is a pest-by-pest discussion on the role of pest management tactics, the use of alternatives (chemical and non-chemical), and the potential of the pipeline pest management tools. Pests are discussed in order of appearance following a typical almond season spray schedule based on tree phenology (dormant, bloom, post-bloom, hull split.). The pest-specific Pest Management Strategic Plan identifies needs in research, regulatory, and education in order for the transition away from "high risk" pesticides to be a success.

Production Regions

There are three major growing regions in California: The southern San Joaquin Valley (Kern, Fresno, Tulare, Madera, and Kings Co.), northern San Joaquin Valley (San Joaquin, Stanislaus and Merced Co.) and the Sacramento Valley (Butte, Glenn, Colusa, Tehama, Sutter, and Yolo Co.).

General Cultural Practices

Deep, fine-sandy loam soils with good internal drainage and freedom from alkali or salinity are best for optimum almond growth and production. Almond trees will not produce commercially acceptable crops under arid California conditions without supplemental irrigation water. Most almond orchards are sprinkler-irrigated, micro-sprinkler irrigated (low volume), or drip irrigated. Only a few are still flood irrigated. Orchard floors are commonly mowed and maintained with the use of herbicides. This entails herbicide-treated tree rows and mowed middles with a cleanup herbicide application prior to harvest. Cultivation in California almond orchards is mostly confined to blocks that practice flood irrigation. Almonds are harvested beginning in July through late-September.

DORMANT SEASON (December – January 31):

Control tactics used during this period target San Jose scale (SJS), European red mite (ERM), brown almond mite (BAM) and the peach twig borer (PTB) and pre-emergence weed applications. Some control measures that are toxic to bees (OPs, carbamates, pyrethroids) must be applied prior to February 1. Almond kernels and leaves are not present at this stage so pesticide residues are not an issue. There is no fruit on the trees during the dormant season.

Worker Activities during the dormant period:

- Soil application of potassium fertilizer.
- Removal, by shakers and poling, and destruction of mummies prior to dormant pesticide applications.
- Pruning, stacking and brush removal typically prior to dormant pesticide applications – not necessarily every year in all orchards.
- Dormant insecticide applications – in some orchards, not generally every year.
- Pre-emergent and/or contact herbicide applications.
- Irrigation in southern San Joaquin Valley.

Insects

The navel orange worm (NOW) is the most important insect pest of almonds. It feeds inside the nut on the kernel and damage occurs after hull split and before harvest. The damage is associated with aflatoxin-producing *Aspergillis* spp. fungi. This insect overwinters in mummified nuts on trees and trash nuts left on the ground. The carob moth is similar to NOW and is controlled in the same manner. Most hard shell cultivars are more resistant to NOW attacks. The peach twig borer (PTB) is a major pest in almonds and a major driver of insecticide use during the dormant stage. The PTB feeds in rapidly growing shoots, especially damaging to first and second year tree scaffold development. Direct feeding on nutmeats causes the greatest economic damage. Soft shell almonds are most susceptible to PTB damage. San Jose scale (SJS) is another major driver of insecticide use during the dormant season particularly in the southern and central regions of the state. SJS suck sap from the plant and inject toxin. The infested branches stop growing and if heavy infestations occur, branches, scaffolds, and fruit spurs can die. If uncontrolled it can reduce production by 10% or more. The European red mite (ERM) and brown almond mite (BAM) are occasional pests that do not normally require in-season treatment. They are controlled by the oil in the dormant spray. The European fruit lecanium (EFL) soft scale and the leafroller complex are secondary pests. Transitioning away from dormant sprays may result in temporary problems with these secondary pests as the role of dormant organophosphates in controlling these pests is not understood.

Navel Orangeworm (NOW):

Chemical Controls:

There are no insecticides used during the dormant period to control NOW.

Non-chemical aids:

- **Winter sanitation methods:**
  - Removal of unharvested almonds by shakers and poling.
  - Nuts on the ground are shred by March 1.
  - Hand poling is used, but is expensive.

Peach Twig Borer (PTB):

Chemical controls:

- **Chlorpyrifos (Lorsban) –** is used by ground application mixed with petroleum oil in the San Joaquin Valley. It is not labeled for dormant season use in the Sacramento Valley due to phytotoxicity to buds. There are surface water concerns.
- **Methidathion (Supracide) –** Available for use, but rarely used due to cost considerations. Worker exposure issues.
- **Diazinon –** is used by ground applications mixed with petroleum oil. Not labeled for in-season use. Growers have voluntarily reduced the use of Diazinon. Surface water concerns.
- **Phosmet (Imidan) -** is rarely used. Less effective.
- **Esfenvalerate** - use, especially at high rates, is very disruptive of predators in mite IPM programs, especially in the San Joaquin Valley. Resistance has been documented in several locations. Most growers are using lower rates to avoid disruption of mites.
- **Permethrin (Ambush/Pounce)** - use, especially at high rates, is very disruptive of predators in mite IPM programs.
- **Carbaryl (Sevin)** - Rarely used, shorter residual so must be used in very late dormant period, but before bloom on pollinators or groundcovers bring bees into the orchards. Used late December or January only. Toxic to honeybees.
- **Spinosad (Success) -** Relatively low toxicity to beneficials and existing mite IPM programs. Expensive. Effective.

Non-chemical Aids:

- None in the dormant stage.

San Jose Scale (SJS):

Chemical controls:

- **Chlorpyrifos (Lorsban)** - is used by ground application mixed with petroleum oil in the San Joaquin Valley. It is not labeled for dormant season use in the Sacramento Valley due to phytotoxicity to buds. There are surface water concerns.
- **Methidathion (Supracide) –** Available for use, but rarely used due to cost considerations. Worker exposure issues.
- **Diazinon –** is used by ground applications mixed with petroleum oil. Not labeled for in-season use. Growers have voluntarily reduced the use of Diazinon. Surface water concerns.
- **Phosmet (Imidan) –** Is an OP but not efficacious.
- **Naled (Dibrom) –**
- **Dormant oils** - can be used alone for scales, but must use high rates.
- **Carbaryl (Sevin)** - Not as effective as the OPs. Rarely used.
- **Buprofezin (Applaud**) **–** New registration. Very effective. Reduced risk material.
- **Pyriproxyfen (Seize) –** Very effective. Fairly expensive. Has a 21 day PHI which limits its use. Can only be used once per growing season. Reduced risk material.

Cultural aids:

- **Monitoring -** Look for scales on twig spurs and branches, also on prunings. No need to spray when scales are not present.

Critical Needs for Dormant Season Insect Control

Research

- Determine efficacy and most beneficial use patterns for emamectin benzoate (Proclaim) for PTB control.
- Develop better sampling methods and economic threshold levels for PTB.
- Further refinement of alternative chemistries: timing, rates, expectations, and efficacy.
- Refine economic threshold levels and monitoring techniques, understand importance of levels of parasitism for SJS control.
- Improve dormant shoot sampling and cost effectiveness for SJS.
- Develop economic thresholds for brown almond and European red mites during the dormant season.
- Study importance of copper as a catalyst for organophosphate degradation.
- Effectiveness of parasites in different growing regions for control of soft scale.
- Study basic biology of leaf roller complexes.

- Develop effective and economical Best Management Practices (BMPs) for watershed protection.
- Identify and assess efficacy and most beneficial use patterns of novel reduced risk chemistries/compounds.
- Improve dormant season application technology.

Regulatory

- Allow for continued judicious use of OPs, particularly in non-sensitive areas.
- Expedite registration of novel reduced risk chemistries/compounds found to be efficacious for navel orangeworm, PTB and SJS control.

Education

- Inform growers on use of new pest management tools as they become available.
- Continue resistance management education programs.
- Provide guidance for proper timing of spray applications.
- Educate producers on dormant sampling techniques.
- Increase awareness of leafroller complex if dormant sprays are not used.
- Educate growers on BMPs for watershed protection.
- Educate regulators on what growers are doing and how effective it is regarding BMPs.

DISEASES

Brown rot, anthracnose, jacket rot/green fruit rot, shot hole, scab, leaf blight, *Alternaria* leaf spot, rust, and hull rot are the most common and devastating fungal diseases of almond. Wood decay disorders also commonly occur in older orchards. Silver leaf disease had recent outbreaks in Stanislaus and Merced Counties. *Phomopsis* wood rot and *Ceratocystis* and *Botryosphaeria* cankers are common diseases. *Armillaria* root rot is an important site-specific problem in some central and northern California growing areas. *Phytophthora* root and crown rots as well as perennial and annual *Phytophthora* canker diseases occur sporadically at low to high incidence throughout the state, with flooding, excessive irrigation, or high rainfall sometimes playing a contributory role. *Verticillium* wilt generally occurs in crop rotations where high populations of the fungus exist. Bacterial diseases such as almond leaf scorch, crown gall, and bacterial blast or canker are also perennial problems in California. Diseases absent or rarely found in California include: leaf curl, *Leucostoma* canker, red leaf blotch, *Rosellinia* root rot, powdery mildew, cotton root rot, and bacterial hyperplastic canker. Phytoplasma (almond brown line and decline - peach yellow leaf roll) and virus diseases (calico, peach mosaic, and peach yellow bud mosaic) have also been reported in California. Numerous other virus diseases have been reported worldwide.

BACTERIAL DISEASES

Bacterial Canker (*Pseudomonas. syringae*) - This is a more serious disease in sandy soils that support ring and lesion nematodes. This disease is active in winter and a young tree infected by bacterial canker usually dies before or during budbreak in the spring. The colder the temperature the higher the incidence of this disease. Symptoms are most obvious in spring, and include limb dieback. Bacterial canker causes isolated cankers on infected limbs that respond by producing amber colored gum. Death of most or all the above ground parts of almond trees may occur in severely infected trees. There may also be leaf spot and blast of young flowers and shoots. Frequently, trees sucker from near ground level; cankers do not extend below ground. *Pseudomonas syringae* (Note: *P. syringae* could also be *Phytophthora syringae* causing confusion.) survives on plant surfaces, is spread by splashing rain, and is favored by high moisture and low temperatures in spring. Vigorous trees are less susceptible to bacterial canker, while young trees, 2 to 8 years old, are more affected.

Chemical controls:

Pre-plant fumigation plus frequent irrigation and post-plant nematicides each fall for the first eight years of orchard life are the only control measures. This is expensive and there is only one post-plant nematicide available. There is no known reliable chemical control for bacterial canker. Therefore, good practices that promote tree health and vigor may help deter bacterial canker. In addition, planting of trees in sandy soils is avoided due to the link between this soil type, high ring nematode populations and increased incidence of the disease.

- **Methyl Bromide + Chloropicrin**
- **Sodium Tetrathiocarbonate (Enzone) -** Controlling nematodes helps reduce severity. Deep enough penetration has been a problem for Enzone to reach the lower layers of soils with tree roots infested with nematodes.
- **Copper –** Some growers' use, but efficacy data are lacking.

Cultural aids:

- Delayed pruning may help.
- Resistant rootstock - Lovell peach rootstock is usually more tolerant than others.
- In light, sandy soils and in some heavy soils, control has been achieved with pre-plant fumigation for nematodes.
- Nutrition – A high nitrogen level reduces severity but causes other problems.
- Irrigation management.

Almond Leaf Scorch

Chemical Controls:

- None.

Cultural aids:

- Pruning.
- Tree removal.

Critical Needs for disease control during the Dormant Season:

Research

- Biology and disease management of almond leaf scorch.
- Research almond silverleaf biology and control.

Regulatory

- Expedite registrations of methyl bromide alternatives.
- Regulatory relief for 1,3-Dichloropropene (Telone) restrictions: Change township caps.
- Expedite other S Inhibitors and anilino pyrimidine fungicide registrations for almonds.
- Expand the usage of SI fungicides for specific diseases such as *Armillaria* (IR-4).

Education

- Educate registrants on importance of SI fungicides in almond industry.
- Resistance management and an understanding of what resistance is and how it occurs.
- As new products become registered, educate growers on use and availability.
- Regional education about disease vulnerability.

WEEDS

In addition to problems at harvest, weeds can cause a multitude of other problems in almond orchards by reducing the growth of young trees because they compete for water, nutrients, and space. Weeds also increase water use, cause vertebrate and invertebrate and other pest problems, and may enhance the potential for disease such as crown rot.
Most orchards are no-till, requiring the use of herbicides and/or mowing to control weeds. The increasing use of more efficient low-volume irrigation systems has increased the need for selective pre-emergence herbicide use in drip, micro sprinkler, and sprinkler-irrigated orchards. Pre-emergent herbicides are generally used only in the tree row (between the trees) while some growers may only use post-emergent materials in these treated strips (middles). This reduces the total amount of herbicides and prevents the surface roots in the tree row from being damaged by cultivation equipment. By treating the tree row only, 25% to 33% of the total acreage is treated. Post-emergent herbicides are typically used year round, but, particularly before harvest to ensure a clean orchard floor.

Selection of weed control methods is dependent on many variables. Many almond growers opt to apply pre-emergence herbicides, typically combinations of materials to cover both broad leaf and grasses as a dormant application before the ground gets too wet with the winter rains. Some growers rely on a mixture of pre-emergent and post-emergent materials at the dormant stage. The main issue is to ensure that the weeds are controlled during bloom when the growers are too busy controlling diseases and water and warmth are available to accelerate weed growth. Soil characteristics have an effect on the weed spectrum (often 15-30 species per orchard), the number of cultivations and irrigations required, and the residual activity of herbicides. Irrigation methods and the amount of irrigation or rainfall affect herbicide selection and the residual control achieved. None of the herbicides provide control of the full spectrum of weeds typically found in an orchard and a combination of herbicides is necessary.

Almond orchards may benefit from plants on the orchard floor if they are carefully managed. These plants in a well-maintained ground cover, can help increase water infiltration, reduce soil compaction, maintain soil organic matter content, cool the orchard, and provide habitat for beneficial insects. Monitoring is used in treatment decisions and herbicide selections are based on dormant and early summer weed surveys.

Chemical controls:

- **Glyphosate (Roundup) –** Post-emergence. Most often used herbicide. Applied during the dormant, pre- and/or post-bloom by ground.
- **Oxyfluorfen (Goal) –** Pre-emergence and/or post-emergence. Applied following harvest up to February 15. Most effective material for *Malva.*
- **Simazine** - Pre-emergence herbicide. Do not use on Mission varieties or those grown on plum rootstocks. Effective on most annual broadleaf weeds and several annual grasses. Only material effective on fleabane and horseweed. Groundwater concerns. Hairy fleabane is a major emerging problem. Moderate to heavy rainfall can affect the residual efficacy of simazine and runoff potential.
- **Paraquat (Gramoxone) –** Post-emergence. Most effective when used on early spring or winter growth of annual broadleaf species in combination with pre-emergence herbicides. Less effective against perennials.
- **Oryzalin (Surflan) –** Pre-emergence. This is registered for bearing and non-bearing use.
- **Norflurazon (Solicam) –** Pre-emergence. Applied pre-bloom by ground. Primarily a nutsedge and grass control material. Can cause minor damage to younger trees or those planted on sandy or sandy loam soils under low-volume irrigation.
- **Trifluralin (Treflan) –** Pre-emergence for annual grasses and some broadleaves.
- **Napropamide (Devrinol) –** Pre-emergence herbicide effective on annual grasses and several annual broadleaves. Must be incorporated with irrigation or rain within four days, which makes it very difficult to use, especially under large acreages.
- **Pendimethalin (Prowl) –** Pre-emergence. Non-bearing trees only. Effective on annual grasses and some broadleaf weeds.
- **EPTC (Eptam) –** Applied pre-emergence by flood irrigation after orchard floor is prepared for harvest to prevent emergence of weeds and grasses. Does control nutsedge.
- **Glufosinate (Rely) –** Post-emergence, contact herbicide. Bearing and non-bearing. Very good on Roundup tolerate weeds, like malva, filaree, nettle and hairy fleabane.
- **Isoxaben (Gallery) –** Pre-emergence. Nonbearing only. Controls broadleaf weeds only.
- **Halosulfuron (Permit) –** Post-emergence nutsedge herbicide with some pre-emergence activity. A lot of label restrictions on uses. Phytotoxicity issues.
- **Thiazopyr (Visor) –** Pre-emergence. Non-bearing only. Controls a wide variety of grass and broadleaf weeds and nutsedge. Must be applied in the fall and again in the winter for nutsedge control.

Critical Needs for weed control during the Dormant Season:

Research:

- Continue to look at Flumioxazin (Chateau) for pre-emergence and some post-emergence control of broadleaves (including fleabane).
- Research alternatives for non-contact herbicides.

Regulatory:

- Water issues for simazine and other herbicides.

Education:

- Continue to monitor for weed species in orchards.
- Educate growers on ways to control hairy fleabane (glyphosate).
- Educate growers on use of glufosinate.
- Educate growers on the use of dormant applications of pre-emergence in non-bearing orchards.
- Educate growers on timing of post-emergence herbicide applications.

BLOOM to PETAL FALL (February 10^{th} – March 15^{th})

The time period for this crop stage varies depending on the region and almond variety but falls within the boundaries stated above (February 10^{th} – March 15^{th}). Organophosphates, carbamates and pyrethroids cannot be used during the bloom stage because of honeybee activity. Control tactics used during this stage primarily target the peach twig borer. This major pest is occasionally controlled during this early season period. Occasionally treatments may be made to control fruit tree leafroller (FTLR), oblique-banded leafroller (OBLR) and webspinning spidermites (WSM) during this period. The FTLR and OBLR feed on leaves, buds and kernels. Webspinning spidermites may be a problem if trees are water-stressed or if there had been late fall populations of WSM. Monitoring for WSM and predators are used as a predictive tool but treatments, if needed, are usually made later.

Worker activities during bloom to petal fall:

- Mowing orchard middles (once).
- Applying spray applications (1-2 times).
- Checking sprinklers, turning on systems for frost protection (0-3 times).
- Monitoring for presence of diseases.

INSECTS

Peach Twig Borer (PTB):
Chemical Controls:

- **Spinosad (Success)** - Not widely used because it is toxic to honeybees and can only be applied at night.

- **Tebufenozide (Confirm) –** Good residual. Fairly weather-fast. New registration. Reduced risk material.
- ***Bt* -** 2-3 applications; typically in combination with fungicides. Timing of applications is critical, and this is not always possible when the orchard floor is too wet for application equipment.

Cultural aids:

- Use scouting for hibernaculae and/or larvae to determine presence of treatable populations and to assist in *Bt* treatment timing.

Critical Needs for insect control during bloom/petal fall:

Research:

- Identify and assess efficacy and most beneficial use patterns of novel reduced risk chemistries/compounds.
- Evaluate emamectin benzoate, diflubenzuron and tebufenozide for rates, timing, efficacy, honeybee toxicity and long-term impact on non-target invertebrates.
- Experiment with efficacy of summer oils for mites and scale.
- Experiment with aerial applications of new materials when soils are too wet.
- Determine role of parasites in FTLR and OBLR control.
- Research efficacy and timing of clothianidin and thiacloprid.

Regulatory:

- Expedite registration of novel reduced risk chemistries/compounds found to be efficacious for navel orangeworm, PTB and SJS control.
- Expedite California registration for diflubenzuron.
- Expedite California registration of methoxyfenozide (Intrepid).

Education:

- Educate growers in the use of new pest management tools as they become available.
- Train growers to scout for hibernaculae and/or larvae for timing treatments.
- Increase awareness of leafroller complex.

DISEASES

Brown rot blossom blight is caused by *Monilinia laxa* or *M. fructicola*. On almond, *M. laxa* is more common than *M. fructicola*. The fungus overwinters in twig cankers or in dead blossom parts. In early spring, the fungus produces grayish sporodochia or "spore pads" where spores are produced. These spores are wind-disseminated to blossoms. Petals, stigmata, and anther filaments of blossoms are susceptible; however, anther and stigmata infections most commonly lead to blossom blight. From blossom infections the fungus grows into spurs causing twig dieback and branch cankers. The disease is favored by high rainfall, high relative humidity, and by moderate to warm temperatures. Protective fungicides are applied from pink-tip to 5% bloom, and at full bloom.

Monilinia species overwinter as mycelium in twigs, peduncles, and mummified fruit. The most important source of inoculum is remaining infected flower parts on which the fungi produce masses of asexual spores beginning in late winter. Brown rot blossom blight affects blossoms and twigs. *M. laxa* is usually more common but *M. fructicola* can be a problem in warmer regions. Of the two brown rot fungi, *M. fructicola* more commonly causes hull rot outbreaks (see hull rot section). The disease occurs in most almond producing areas in California and is worse when rains or fog occur during bloom. Almost complete crop loss can be experienced on susceptible cultivars when rain persists during bloom. Control of brown rot depends on protecting blossoms from infection from popcorn stage through bloom. Applications begin at pink bud and continue on at full bloom and petal fall. Blossom applications of fungicides are generally the most effective management measures for blossom blight control when properly applied using air or ground equipment.

Chemical control: See fungicide table for resistance risk for each chemical.

- **Azoxystrobin (Abound) –** Effective against brown rot. Apply at full bloom to be most efficacious for this disease. No local systemic action.
- **Benomyl (Benlate) -** was canceled but product can still be used until supplies exhausted (Tolerance will be revoked for nuts as of 1/1/07). Mostly used during bloom. Apply at pink bud only and use a companion fungicide of different chemistry. Resistance has been documented in the Sacramento and northern San Joaquin Valleys.
- **Captan -** This is mostly used during bloom to petal fall. Do not apply in combination with, immediately before, or closely following oil sprays. Potential negative effects on honey bee brood limit its use during bloom.
- **Cyprodinil (Vangard)** - Excellent against brown rot blossom blight. Reduced risk material.
- **Iprodione (Rovral) -** Addition of a narrow-range oil at 1-2% increases the effectiveness of this material. Good brown rot material, excellent when combined with oil, however, water quality can seriously affect performance. Cannot be applied after petal fall per label restriction.
- **Maneb -** Generally, not the most effective brown rot material because it is a contact fungicide. Rarely used specifically for brown rot.
- **Myclobutanil (Rally) -** A very effective treatment since the formulation changed to an emulsifiable concentrate.
- **Thiophanate-methyl (Topsin-M) -** Excellent for brown rot control. Cannot be applied after petal fall per label restriction. Resistance has been documented in the Sacramento and northern San Joaquin Valleys since the late 1970s.

Cultural control:

- Pruning infected twigs helps to reduce inoculum, but the most effective practice is disease prevention with the use of fungicides.

Alternatives not currently registered:

- **Pyrimethanil (Scala)**
- **Pyraclostrobin/nicobifen (Pristine)**

Jacket Rot/Green Fruit Rot: This disease can be caused by *Monilinia* species, *Botrytis cinerea*, or *Sclerotinia sclerotiorum*. Spores of *M. laxa* are produced on blighted blossoms or twig cankers, whereas spores of *B. cinerea* are produced on dead or dying tissues of a number of plants including almond and weed species common in almond orchards. Fruiting bodies called apothecia are produced by *S. sclerotiorum* from soil-borne, resistant overwintering structures known as sclerotia. Apothecia produce spores called ascospores that are forcibly discharged and wind disseminated to senescing blossom tissues. Once a flower is fertilized and the ovary enlarges, the floral tube (jacket) splits and separates from the peduncle.

The flower parts usually dry out and drop off quickly in dry weather as the immature fruit develops. In wet weather the flower tissues remain attached and provide a substrate for these fungi to colonize the developing fruit. Symptoms usually develop one to three weeks after petal fall. Green fruit rot, however, can also occur in years of wet weather and heavy fruit set when non-thinned fruit are in contact with each other or from an infected jacket.

Chemical Control: This disease is usually controlled by applications for other bloom time fungal diseases. In the past, full bloom applications of fungicides such as benomyl or iprodione have provided effective control. Recently, with the introduction of newer compounds such as the DMI fungicides and the strobilurins, management of this disease is more difficult because these compounds are less effective against *B. cinerea*.

- **Benomyl**
- **Captan**
- **Cyprodinil –** Most effective material. Use with oil can be phytotoxic.
- **Iprodione –** Very effective material. More effective with oil.
- **Thiophanate methyl**
- **Ziram –** May be tank mixed with other materials.

Cultural

- None

Colletotrichum **(**Anthracnose**) -** This disease was not considered a problem in California until the early 1990s. The fungus is now found in all major almond growing regions of California and is considered a major threat to the industry. This disease is caused by *Colletotrichum acutatum*. The fungus overwinters in dead wood or in mummified fruit that remain attached to the tree. White mycelium of the fungus is commonly found in anthracnose mummies that are split open. Spores of the fungus are produced on all infected tissues during wet conditions and are disseminated by splashing water. Blossoms, leaves, and fruit (through hull split) can be infected. Infected blossoms become blighted similar to brown rot blossom blight but with orangish spore droplets (acervuli) on the floral cup (hypanthium). Leaf infections are yellow irregular lesions that begin at the leaf margin or tip and advance toward the middle of the leaf. Orange, depressed lesions on the hull are typical early season fruit infections. Fruit infections frequently develop into the kernel. Late season fruit infections (May-June) are orange to tan and commonly develop profuse amber-colored gum. As the season progresses, fruit infections develop into woody tissue, resulting in dieback of spurs, twigs, and branches. Leaf wilting and yellowing are additional symptoms of dieback.

The fungus overwinters in dead wood or in mummified fruit that remain attached to the tree.

Chemical Controls:

- **Azoxystrobin (Abound) –** Currently one of the most effective fungicides for managing anthracnose.
- **Captan** - Control of anthracnose is moderate. Important resistance management tool when used in combination with other materials.
- **Myclobutanil (Rally)** - Moderately effective.
- **Maneb** - Control of anthracnose is variable. Resistance management tool when used in combination with other materials.
- **Trifloxystrobin (Flint)** - Currently one of the most effective fungicides for managing anthracnose. More expensive than the alternatives.
- **Ziram**- Control of anthracnose is moderate. Important resistance management tool when used in combination with other materials.

Cultural

- Dormant season mummy removal and pruning out dead wood reduces inoculum and severity of disease.
- Low-angle irrigation that reduces canopy wetness also reduces severity of disease.
- Varietal susceptibility could be a consideration when planting.

Critical Needs for disease control during the bloom/petal fall:

Research

- Continued development of fungicide alternatives for resistance management of foliar and bloom diseases.

Regulatory

- Change iprodione (Rovral) label to reflect same rates and PHI as found on other stonefruits.
- Expedite registration of propiconazole, tebuconazole or other triazole registrations.

Education

- None

WEEDS
Controlling weeds during this stage of growth in the middles can be an important tool for frost protection (bare soil reradiates more energy). Growers tend to be busy with fungal control. Need to ensure weeds do not get too big, when control becomes more difficult or even allows seed set.

Chemical Control: Same and discussed previously.

Critical Needs for weed control during the bloom/petal fall:
Research
- None.

Regulatory
- None.

Education
- Continue to monitor for weed species in orchards.
- Educate growers on ways to control hairy fleabane and other troublesome weeds.
- Educate growers on the use of glufosinate.
- Educate growers on timing of post-emergence herbicide applications.

POST BLOOM: (March 16th – June 30)

Control tactics applied during the post bloom stage are targeting peach twig borer and San Jose scale. These 'May' sprays are seldom applied on bearing trees in the north and only occasionally in the south due to perturbation of mite populations. Growers prefer not to spray at this time, as sprays can be more disruptive of natural enemies for the remainder of the season. PTB controls may also reduce NOW, OFM, OBLR and FTLR, especially if timed to phonological development of these insects using degree-day models. Rarely, in-season control of San Jose scale may be needed if dormant sprays were not applied and monitoring indicates high levels of scales (Sacramento and northern San Joaquin Valleys). Control is targeted to the "crawler stage." SJS sucks sap from plant and injects a toxin– infested branches stop growing and if heavy infestations occur, branches, scaffolds, and fruit spurs can die; if uncontrolled SJS can reduce production by 10% or more.

Worker activities during this post bloom stage: (mostly mechanical operations)
- Mowing orchard middles (3 times).
- Applying spray application for insect and disease control (once).
- Applying nitrogen fertilizer (once).
- Checking and maintaining sprinklers.
- Turning on systems for frost protection or irrigation (3 times).
- Monitoring for presence of diseases.

- Pruning out dead wood (0-once).
- Placing insect traps in orchards and monitoring them for spring biofixes.

Insects

Peach Twig Borer (PTB)

Chemical controls:

- **Phosmet (Imidan) –** Used post bloom because of toxicity to bees.
- **Chlorpyrifos (Lorsban) -** Not as effective as other organophosphates.
- **Azinphos-methyl (Guthion) –** 3-14 day activity related REI, 28 day PHI. Used only post bloom because of bee toxicity.
- **Esfenvalerate (Asana) -** Upsets predators in established mite IPM programs. This may be used to control PTB during cool wet springs when mite activity is reduced and populations are low.
- **Permethrin (Ambush/Pounce) -** Upsets predators in established mite IPM programs at high rates.
- **Spinosad (Success) -** Very effective, but expensive. Believed to be least disruptive to mite IPM programs, but the beneficial six-spotted thrips may be adversely affected.
- **Carbaryl (Sevin) -** rarely used because of mite flare-ups.
- ***Bt* -** More effective during bloom and immediately post-bloom rather than during the May spray because of poorer coverage once leaf canopy is developed and because of short residual activity relative to the emergence period in May.
- **Tebufenozide (Confirm) –** Recently registered. Promising, but has not proven to be particularly effective.

Cultural aids:

- Northern regions – monitor for biofix to help time future treatments.
- Mating Disruption – has been used for PTB in more high value 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. Organic growers use this method for control, although *Bt* bloom sprays would be a less expensive alternative.

Navel Orangeworm – not typically treated at this time.

Biological Control

- ***Goniozus legneri*** – parasitic wasp releases – helpful as ongoing releases.

San Jose Scale (SJS)

Chemical control:

- **Chlorpyrifos (Lorsban) –** localized areas of resistance can be found, particularly in the southern San Joaquin Valley.
- **Methidathion (Supracide) –** Rarely used. Expensive. Worker safety concerns.
- **Phosmet (Imidan)** - Not used, not effective.

- **Summer oils –** Fairly effective. Also suppresses mites.
- **Pyriproxyfen (Knack) –** rarely used at this time. Effective.

Cultural aids:

- Day-degree models for predicting crawler emergence.
- Sticky tape to monitor for crawler activity.
- Pheromone traps for determining biofix, spray timing and beneficial populations.

European red mite (ERM), Brown almond mite (BAM), and Webspinning mites (WSM)

Chemical control:

- **Propargite (Omite) -** Some resistance is beginning to show up.
- **Abamectin (Agri-Mek) plus oil**
- **Fenbutatin oxide (Vendex) -** Some local spots of resistance are showing up. Must be applied during warm temperatures for good efficacy. Coverage is important.
- **Pyridaben (Nexter) -** Not used due to expense and variable efficacy. Short residual.
- **Clofentezine (Apollo) -** An ovicide, therefore spring is the only effective timing for a spray. Preventative material.
- **Narrow range oils –** effective.
- **Hexythiazox (Savey) –** effective ovicide, but also kills WSM immatures.

Cultural aids:

- Predatory mite releases (most effective during spring before WSM populations build).
- Monitoring and sampling for presence/absence of both WSM and predators.
- Dust control - Excessive dust inhibits control of all miticides and interferes with predators.
- Irrigation Management – Avoid water stress which increases mite populations.

American Plum Borer/Peach Tree Borer

Chemical control:

- **Chlorpyrifos (Lorsban)**

Cultural aids:

- Keep trees healthy.
- Prune out damaged areas.

Critical Needs for Insect Control During the Post Bloom Period:

Research:

- Evaluate and gray field ant as potential predators of PTB.
- Improve pheromone disruption programs for PTB as current methods are not cost-effective due to the long use season and high cost of pheromones.
- Determine most efficacious timing of *Bt* sprays and ways to extend residual activity to control PTB.
- Identify and assess efficacy and most beneficial use patterns of novel reduced risk chemistries/compounds.
- Determine proper timing, rates, and application methods for emamectin benzoate and diflubenzuron.
- Modify and improve current monitoring systems and economic threshold level models for SJS.
- Evaluate parasitism differences in SJS between northern and southern growing regions in relation to tree spacing.
- Study efficacy, rates, and timing of kaolin for control of SJS.
- Research rates and dilutions of oil for SJS control.
- Develop an effective monitoring system for parasitoids of SJS.
- Increase knowledge regarding resistance management.
- Fine-tune rearing and release of *G. legneri* for control of NOW.
- Fine-tune pheromone monitoring systems for APB.
- Develop egg identification system for boxelder bugs, leaffooted bugs and stink bugs.
- Study the biology and behavior of boxelder bugs, leaffooted bugs and stink bugs.
- Study biology and emergence of ten-lined June beetle.
- Identify and evaluate pheromones as a monitoring tool and possible control for ten-lined June beetle.
- Track glassy-winged sharpshooter (GWSS) expansion.
- Study basic biology of GWSS, determine susceptibility of almond to infestation by GWSS and susceptibility of almond varieties to Almond Leaf Scorch.
- Test efficacy of control measures for GWSS.
- Determine effects of fungicides on spider mite outbreaks later in the season.

Regulatory:

- Expedite registration of imidacloprid for control of GWSS.
- Expedite registration of novel reduced risk chemistries/compounds found to be efficacious for navel orangeworm, PTB and SJS control.
- Preserve breadth of control options to slow resistance and reduce potential for non-target excesses.

Education:

- Inform growers of new techniques as they are developed and become available.
- Explain monitoring techniques and economic threshold calculations.
- Increase awareness in resistance management practices.

- Inform growers regarding the development of parasitoid release programs, timing and numbers as this becomes refined to control NOW.
- Distribute GWSS identification brochures.

Diseases

Leaf rust, caused by *Tranzschelia discolor* f. sp. *dulcis* typically develops in summer and fall. The fungus preferentially attacks almond, whereas other forms occur on prune or peach. Leaf symptoms are angular, chlorotic lesions on the upper leaf surface and rusty brown masses of urediniospores *only* on the lower leaf surface. Leaf rust can cause severe defoliation in a short period of time if conditions are favorable. Almond fruit are not infected. The fungus has a complex life cycle with up to five spore stages and has been reported from alternate hosts. In California, the fungus survives as urediniospores infesting buds and branches and occasionally as mycelium in one-year-old stem cankers.

Chemical Controls:

- **Azoxystrobin (Abound) –** One of the most effective fungicides for managing leaf rust.
- **Maneb –** An effective treatment. A resistance management tool when used in combination with other materials. Long PHI creates limitations on use.
- **Sulfur/(Wettable sulfur) –** Applied during spring and summer seasons. Used as a preventative treatment. Various application rates are used but 20 lb/A is commonly used for rust management. Do not apply within 3 weeks of an oil application.
- **Trifloxystrobin (Flint) –** One of the most effective fungicides for managing leaf rust.

Cultural control: Cultural control practices have not been developed; however, disease is most severe in lowland areas and high-density orchards with poor air-circulation and long wetness periods from dew or rain. Some varietal differences, e.g., Ne Plus Ultra, Sonora, Padre and Carmel are highly susceptible. Younger trees are more susceptible than older trees.

***Alternaria* leaf spot -** Is caused by several fungi in the *Alternaria alternata* complex. The disease develops in late spring and through summer. Infections are brown, circular lesions that coalesce into large, irregular necrotic zones on leaf. Lesions often become black in the center where numerous spores are produced. Spores are dark and multi-celled with septa at oblique or right angles. In orchards with poor ventilation, high humidity, and prolonged periods of leaf wetness (e.g., dew, high angle irrigation), trees commonly defoliate from severe *Alternaria* leaf spot infections.

Chemical Controls:

- **Azoxystrobin (Abound) –** One of the most effective fungicides for managing *Alternaria*.
- **Trifloxystrobin (Flint) –** This is as good as or better than azoxystrobin.

Cultural control: Designs of orchard planting should allow adequate air movement (wider tree spacing) and sub-surface irrigation systems do decrease relative humidity.

Shot hole - Is caused by *Wilsonomyces carpophilus* (synonym *Stigmina carpophila*). Leaf and fruit infections can result in defoliation or premature nut drop, respectively. Leaf symptoms include circular, tan lesions that may coalesce. At cool temperatures (59º F), lesions develop purplish margins and remain attached to leaves. At warmer temperatures (68º F), lesion margins are chlorotic and lesions commonly abscise resulting in the characteristic "shot hole" symptom. Once sporodochia are present, an epidemic outbreak may occur when spores are splash dispersed by water to healthy leaves and fruit. Infections on older fruit are circular, raised, corky lesions that do not develop deep into the hull. Clear to light yellow-colored gumming is associated with abscised lesions on fruit. In wet, cool weather, lesions commonly remain attached to leaves long enough for the fungus to produce brown to black sporodochia that contain numerous, multi-celled, pigmented spores. The fungus overwinters as spores on buds and branches of almond trees.

Shot hole attacks both leaves and young fruit and can result in defoliation or premature nut drop. Almost complete defoliation can occur when rain persists throughout the spring, resulting in a reduction in photosynthesis and weakening of the trees.

Occurs from bloom to petal fall, but may still apply into next stage as long as conditions exist.

Chemical Controls. Contact fungicides serve as protectants, not eradicants, and provide control only if they are applied so foliage and fruit are completely covered before a wet period.

- **Azoxystrobin (Abound)** – an effective fungicide for managing shothole. More of a suppressant material.
- **Captan** - One of two of the most effective shot hole control materials ever developed. Important resistance management tool when used in combination with other materials.
- **Myclobutanil (Rally)** - Moderately effective.
- **Maneb** - An effective treatment. Resistance management tool when used in combination with other materials.
- **Trifloxystrobin (Flint)** - an effective fungicide for managing shothole.
- **Ziram-** - One of two of the most effective shot hole control materials ever developed. Important resistance management tool when used in combination with other materials.
- **Iprodione (Rovral) –** Very good control. Used only through petal fall.

Cultural control:

- Low-angle irrigation that reduces canopy wetness also reduces severity of disease.
- Fall zinc sulfate nutritional applications can defoliate and reduce inoculum levels.

Scab is caused by *Cladosporium carpophilum*. The organism overwinters as mycelium in twig lesions and sporulates on these lesions beginning in late March. Spores are variable in shape ranging from lemon- to cigar-shaped and commonly have two bud scars, one on each end of the spore. These spores are wind disseminated and infect leaves, fruit, and new shoots during the spring and summer. Symptoms develop slowly and begin as yellow spots on leaves in late spring (May-June). Lesions then become grayish and circular and later irregular and necrotic. In transmitted light, leaf lesions appear chlorotic or necrotic. Fruit lesions are superficial, black, circular spots that may coalesce. Hull symptoms develop in late spring and summer and do not result in crop loss. However, infected leaves drop and can reduce photosynthesis that may eventually weaken the tree, impact fruit bud production and ultimately reduce yield. The disease severely affects Carmel, NePlus Ultra, Butte, and Peerless, whereas Nonpareil is less susceptible.

Chemical Controls: Treatments must be applied before scab symptoms appear, which can be anytime from late spring through fall. Effective timing of fungicides include petal fall and early spring applications.

- **Benomyl (Benlate) –** A highly effective scab control material but resistance to this class of fungicide has been reported. Was canceled but product can still be used until supplies exhausted (tolerance will be revokes as of 1/1/07). Mostly used during bloom.
- **Azoxystrobin (Abound) –** One of the most effective fungicides for managing scab.
- **Thiophanate-methyl (Topsin-M) –** same as Benlate for control.
- **Captan** - Is an effective treatment. Important resistance management tool when used in combination with other materials.
- **Maneb –** Is an effective treatment. A resistance management tool when used in combination with other materials.
- **Sulfur/Lime sulfur –** Applied during dormant (lime sulfur) and in spring and summer seasons (Wettable Sulfur). Incompatible with oils and propargite. Has potential to flare web-spinning mites.
- **Trifloxystrobin (Flint)** - an effective fungicide for managing scab.
- **Ziram** - is an effective treatment. Important resistance management tool when used in combination with other materials.

Cultural control:

- Low-angle irrigation that reduces canopy wetness also reduces severity of disease.

Hull rot

Chemical

- None.

Cultural

- Irrigation management and nutrition management reduces severity by up to 75%.
- Avoid excess nitrogen.

Leaf blight

Chemical controls
- **Azoxystrobin (Abound)**
- **Captan**
- **Maneb**
- **Ziram**

Cultural
- None

Critical needs for disease control during the post bloom period:

Research
- None.

Regulatory
- Effective alternatives to strobilurins for *Alternaria* control – triazoles (Propiconazole, tebuconazole, etc.).

Education
- None.

HULL SPLIT (July 1- 31) – HARVEST (Late July – October depending on variety and location)

Control tactics during this growth period usually target the second generation of PTB and NOW. In the Southern growing regions miticides are frequently tank-mixed with insecticides. Roughly 5 - 30% of the growers in the North, 50% of the growers in the Central region, and 70-90% of the growers in the Southern region use hull split sprays. Ants occur mid-June through late August and are a major pest of almonds, particularly in the Southern regions. They feed directly on the nuts and are bothersome to farm personnel. The Oriental fruit moth (OFM) is an occasional pest at this time and management tools for NOW and PTB usually control some OFM. High populations require sprays specifically timed for this insect as the most susceptible periods do not always coincide with other key pests. Leafhoppers can be occasional pest in the Northern growing regions but rarely require control. In the San Joaquin Valley the leafhopper has become a widespread pest that requires treatment.

Hull split sprays are timed for early hull split on the earliest worm susceptible variety (usually Nonpareil) and insect effective residues need to persist through the hull split period covering the later splitting (pollinator varieties) nuts. Because NOW and PTB can not be controlled once they enter the nuts, long residual insecticides are needed to protect the nuts once hulls begin to split. The most effective control is one that kills adults or newly hatched larvae before they can enter. Long residuals of insecticides for control of

NOW and PTB are also desired because of the difficulty scheduling sprays during harvest. Each almond variety is harvested separately when ripe and allowed to dry in the orchard. Thus the completion of harvest of an almond orchard includes 2-3 shaker runs, dryings and pickups, which takes 4-8 weeks to complete. Especially NOW can complete another lifecycle during this time. The long PHIs for most insecticides and the business of harvest preclude spraying between harvests.

Worker activities during the hull split to harvest: (mostly mechanical operations)

- Mowing orchard middles (1-2 times).
- Spraying herbicides in tree rows.
- Applying hullsplit spray or pre-harvest herbicide applications (1 time).
- Applying nitrogen fertilizer (0-once).
- Checking and maintaining sprinklers.
- Turning on irrigation systems (2 times).
- Pruning out and picking up dead wood (0-once).
- Monitoring insect traps.
- Harvesting (includes driving shakers, sweepers and pickup machines).

Peach Twig Borer (PTB):

Chemical controls:

- **Azinphos-methyl (Guthion) –** 30 day REI and 30 day PHI limit its use during harvest period.
- **Phosmet (Imidan) –** has a 3-day REI but has a 30 day PHI that limits it use close to harvest.
- **Chlorpyrifos (Lorsban) –** There is a 14 day PHI and a 48 hour REI that limits it use just before harvest.
- **Carbaryl (Sevin)** - Rarely used at this stage. It has a 14 day PHI so cannot be used just before harvest. This use disrupts mite IPM programs.
- **Permethrin (Ambush/Pounce)** - Rarely used. This use disrupts mite IPM programs.
- **Esfenvalerate (Asana) -** Occasional use only. This has a 21-day PHI which limits it's use. This use also disrupts mite IPM programs.
- ***Bt* –** Requires more than one spray due to short residual activity.
- **Spinosad (Success) –** Is rarely used. Questionable efficacy at this treatment timing.
- **Tebufenozide (Confirm) –** Is occasionally used. Fair efficacy.

Cultural aids:

- Monitoring with pheromones.
- Use of day-degree models to track generations and to predict timing of applications.

Navel Orange Worms (NOW) – Navel orangeworm is a primary pest of almonds in California and is found on several hosts. Eggs are laid on mummy nuts in the trees or new crop nuts and hatch within 4 to 23 days, depending on temperature. Eggs are not laid on new crop nuts until initiation of hull split. A degree-day model which uses a spring biofix can help predict occurrence of oviposition relative to hullsplit. Treatment is timed to hullsplit unless the NOW flight begins after hullsplit, and then sprays are timed to oviposition. Newly hatched larvae are reddish orange and later vary from milky white to pink in color. The larvae overwinter in mummy nuts either in trees or on the ground. First instar larvae bore into the nutmeat and later instars can consume most of the nut, producing large amounts of webbing and frass. Navel orangeworm larval damage can also lead to fungal infections. Some cultivars are more susceptible to damage, especially later maturing, softshell almonds with a lengthy hull split period or a poor shell seal. (Reference www.ipm.ucdavis.edu)

Chemical controls currently used:

- **Azinphos-methyl (Guthion)**
- **Phosmet (Imidan) –** Not as effective as other organophosphates against NOW.
- **Chlorpyrifos (Lorsban) –** Mostly use is for ants and peach twig borer control. Has some activity on NOW.
- **Carbaryl (Sevin) –** Not used. It is extremely disruptive to natural enemies and will generally cause mite outbreaks.
- **Permethrin (Ambush/Pounce) -** This use disrupts mite IPM programs if used at high rates, it can be used at low (4 oz.) rates with minimal mite problems. Usefulness of this material is limited due to severe mite flare-ups following its use during the growing season.
- **Esfenvalerate (Asana) –** Effective, but this use disrupts mite IPM programs.
- **Diazinon –** is not registered for in-season use in California, therefore not used to control NOW.
- **Malathion –**Is not effective against NOW.
- ***Bt* -** More than one spray is needed due to short residual activity and efficacy has not been shown.
- **Spinosad (Success) -** Low efficacy has been demonstrated.

Cultural aids:

- Early and rapid harvest to remove the nuts from the orchard to prevent egg laying and infestation.
- Egg traps and day degree models are used to predict third generation occurrence, helps in predicting when to harvest relative to NOW flight.

Ants – Ants have caused considerable damage to almond crops ever since growers adopted more efficient water management practices. The use of low volume irrigation, either by drip or microsprinkler, has allowed ants to colonize much larger portions of orchard floors leading to larger ant populations. In addition, less tillage, with consequent increase in the native annual vegetation and planted covercrops, provides an abundant food source of seeds to maintain high ant populations. Ants cause damage primarily after the almonds are shaken from the trees. As the nuts lay on the ground ants enter the shell and feed on the nutmeats inside. This results in lowering of the grade of the harvest product. Damage to nutmeats can reach 50% or more. Reduction of yield is usually insignificant. Some damage occurs from ants climbing into the trees and feeding on the nuts still hanging but it is insignificant compared to the amount of damage on the ground.

There are two established species that cause most of the damage to almond kernels- the southern fire ant (SFA) *Solenopsis xyloni* McCook, and the pavement ant (PA), *Tetramorium caespitum* (Linnaeus). SFA occurs throughout most of California and is the major damaging species in the San Joaquin Valley. PA occurs in orchards from approximately Merced County through the Sacramento valley. If red imported fire ant (RIFA), *Solenopsis wagneri* Santschi, becomes established in central and northern California, it, too, will cause major damage and may also interfere with currently used harvest practices. Another species, the thief ant, *Solenopsis molesta*, occurs sporadically in orchards and occasionally can cause significant damage.

Insecticides currently used:

- **Chlorpyrifos (Lorsban) –** Applied to the orchard floor close to harvest.
- **Abamectin (Clinch)**
- **Pyriproxyfen (Knack)**
- **Permethrin (Ambush/Pounce) –** Not very effective. Quick knock down, but no residual activity.

Cultural control:

- Rapid pickup of nuts following harvest is important in minimizing ant damage.
- Scouting: Use of hot dog baits. This procedure uses a small piece of hotdog (CDFA uses small pieces of Spam) in a snap-top vial to trap ants. The vials are placed throughout the orchard for red imported fire ants and left for a few hours after which they're picked up, the caps closed, and ant species identified and counted.

Critical needs for Insect control during the hull split to harvest period:

Research:

- Determine mitigation measures necessary to allow for continued use of OPs.
- Identify economic thresholds for PTB.
- Identify and assess efficacy and most beneficial use patterns of novel reduced risk chemistries/compounds. Evaluate Soybean oil for efficacy against NOW.
- Determine timing of PTB generations in relation to crop susceptibility and harvest (a hull split predictive model).
- Study methods to improve pheromone mating disruption techniques and cost effectiveness for PTB.
- Determine NOW response to pheromone.

- Refine use of pheromone puffer dispersal systems and determine methods to allow the practice to be more cost effective.
- Determine if mating disruption would be efficacious for NOW.
- Develop economic threshold models and more refined monitoring systems for NOW.
- Determine efficacy, timing, and placement of boric acid for ant control.
- Determine efficacy of fipronil for ant control.
- Experiment with baiting materials and the placement of baits for ants.
- Economic threshold studies and monitoring methods for ants (not well developed for social insects).
- Research needed to confirm efficacy of for control of ten-lined June beetle.

Regulatory:
- Allow for continued judicious use of OPs to prevent major outbreaks of secondary pests.
- Expedite registrations of emamectin benzoate and tebufenozide for PTB and NOW control.
- Expedite registration of fipronil for ant control.
- Expedite registration of novel reduced risk chemistries/compounds found to be efficacious for navel orangeworm, PTB and SJS control.
- Work with industry to determine ways of reducing PHI and REI for OPs.
- Air quality problems due to harvest.

Education:
- Inform growers about use of new management tools as they become available.
- Better communications with growers regarding new management tools as they become available.
- More widely distribute information on NOW degree-day model.
- Inform registrants of the need for insecticides with shorter PHIs.

Weeds

Chemical control

- 2-4-D – Applied as a directed spray post-bloom by ground. Useful for controlling troublesome perennials. Some local regulatory restrictions because of toxicity to other crops and temperatures during and following application.
- Glyphosate (Round-up) may be applied, typically as spot treatments, if weeds start to emerge before the last harvest has been completed

Critical Needs for weed control during Hull Split – Harvest stage

- None

SOILBORNE PESTS AND DISEASES (Those manifested or managed at irregular intervals throughout an orchard's lifetime)

Diseases caused by *Phytophthora* spp.

More than 10 different *Phytophthora* species are known to cause crown and root rot and/or aboveground canker diseases on almond. The pathogens all are soilborne and can be spread among orchards via infested canal or river water, soil adhering to equipment, or infested planting stock. Overall incidence of the diseases typically is low (i.e., less than 1%), although they sporadically cause high incidence of tree death (i.e., 5% or more) in individual orchards. Generally, crown and root rots occur at highest incidence and severity in relatively young orchards, while the perennial canker diseases occur more frequently in mature, bearing orchards, although almond trees of all ages are susceptible to the pathogen. Periods of 24 hours or more of saturated soil favor *Phytophthora* infections. Conversely, good soil drainage and more frequent but shorter irrigations reduce the risk of root and crown rot. Also planting trees on a berm reduces the chances of this disease. Sprays containing phosphonate have helped to prevent perennial Phytophthora cankers.

Chemical controls currently used:

- **Mefenoxam (Ridomil Gold) –** For post-plant application to soil around non-bearing and bearing trees. Do not apply more than 3 applications per year. Apply early spring and fall. Expense, practicality of use and timing limit effectiveness.
- **Fosetyl-al (Aliette)** is applied to less than 1% of the acres by ground at an average rate of 5.0 lbs. a.i. per acre. It is used as a post-plant treatment for nonbearing trees only. It is a foliar spray, 60-day intervals. Non-bearing trees only. Expense, practicality of use and timing limit effectiveness.

Cultural control: Main control strategies for *Phytophthora* root rot.

- **Rootstock selection**. Rootstocks vary in susceptibility to the different *Phytophthora* species; none are resistant to all species.
- **Soil moisture management –** Plant on soil with good surface and internal drainage. Plant on ridges to keep standing water from around the base of the trees. Irrigate to fully meet tree's water needs, but avoid prolonged soil water saturation (i.e., >24 hr) and over irrigation.

Replant Disease

Replant disease can result in poor growth of almond orchards that are replanted without precautions after recent removal of old stone fruit or nut orchards. It is manifested primarily in the first year after planting, and in severe cases high percentages of the trees die or fail to grow. The disease is thought to involve biological agent(s) and to be distinct from nematode induced disease, because it can be prevented by several diverse biocidal treatments (including most broad-spectrum fumigants), and it occurs in the absence of significant nematode pest populations. Replant disease also has been referred to as "replant disorder."

Armillaria (oak root fungus) - Has no effective control measures other than cultural.

Cultural control:

- Resistant rootstock.
- Avoid over-irrigation.
- Remove all old roots from previous infected trees when replanting.
- Avoid ripping or leveling that would spread infected root pieces.

***Verticillium* wilt -** *Verticillium dahliae* is a soil-inhabiting fungus found in nearly all soils in the temperate regions of the world. *Verticillium* wilt only attacks young trees less than 5 years old.

Pre-plant fumigation treatments

- **Methyl Bromide** + **Chloropicrin** (Telone C35) – Used as a pre-plant treatment when replanting into soils previously in orchard crops or other crops harboring large populations of nematode pests of almond. Most effective when tarped, however expensive so most is shanked. All diseases.

- **1,3 Dichloropropene (Telone)**– This is the closest replacement for methyl bromide, but its use for this purpose in California was suspended from 1990 to 1996 and today there are serious acreage restrictions for 1,3-D (township caps) and a limitation of 350 lb. per acre associated with its use. All diseases.

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- **Metam-Sodium (Vapam)** – applied at individual tree sites pre-plant. This material is difficult to move deep enough into the soil to be of much use.

- **Fenamiphos (Nemacur)** – Registration to be phased out by 5/31/2007. Non-bearing trees only. .

- **Sodium Tetrathiocarbonate (Enzone)** – Several small-scale field trials have shown that flood applications of this material can reduce ring nematode populations on almonds, thereby reducing the incidence of bacterial canker. Not as effective as methyl bromide. Application conditions are critical for effectiveness.

Cultural aids:

- Irrigation management
- Selection of an orchard site where cotton, cucurbits, tomato, melons, potato or other susceptible crops have never grown is important to prevent this disease.
- When establishing a new orchard, avoid using intercrops that are hosts of this fungus.
- Solarization – Can be effective if disease is in top 12 inches of soil.

Crown gall - Is caused by the bacterial pathogen *Agrobacterium tumefaciens*. Galls commonly occur on roots, crowns, and stems. Smooth, young galls enlarge to become woody tumors with irregular surfaces. The disease can occur on nursery, young, or mature trees. Soil temperature of 22 C and moisture of 60% is most favorable for disease development. Management techniques that reduce populations of the bacterial pathogen include soil fumigation and disinfestation of equipment with sodium hypochlorite. Biological control has been used successfully with the use of a nonpathogenic strain *A. radiobacter*.

Chemical controls: (Soil fumigants are used in nursery operations but are not completely effective in managing the disease.)

- **Gallex** – used to selectively kill tumors on individual trees in existing orchards. The treatment is most effective when used on trees 4 years old or less. This procedure is expensive and difficult to carry out. Rarely, if ever, used on almonds since the dead wood that results from treatment typically becomes infected with secondary wood decay fungi that weaken structural strength, ultimately resulting in tree loss due to wind throw. *Agrobacterium tumifacians*-84 (previously *A. radiobacter*) – used as a root spray or dip before planting. Biological control using a strain of A*. radiobacter*, (e.g., Galltrol) is used during planting of trees at orchard sites. Site exclusion of the pathogen with this competitive root colonizing bacterium.

Cultural aids:

- Prevention of injury to trees during planting and cultural practices.
- Purchase young trees from a reputable nursery, plant them with a minimum of handling, and avoid root injuries.
- Sodium hypochlorite is used to disinfest equipment used during planting by nursery and orchard operations.
- Rootstock selection.

Soil fumigants:

- **Methyl Bromide**
- **Sodium Tetrathiocarbonate (Enzone)**

Research

- Fumigant alternatives to methyl bromide and better understanding of replant disorder.

<u>Nematodes</u> (Pre-plant and Post-plant)

The most common nematode pests of almond are root knot nematodes (*Meloidogyne* spp.) the root lesion nematode (*Pratylenchus vulnus*), the ring nematode (*Mesocriconema* *xenoplax*), and the dagger nematode (*Xiphenema americanum*). They damage almond trees of all ages directly by feeding on the roots, but young trees are most severely affected, due the small size and vulnerability of their developing root systems. The ring nematode predisposes young trees to bacterial canker disease.

Pre-plant - California suspension of all 1,3-dichloropropene (1,3-D) registrations in 1990 shifted fumigant preference to methyl bromide (MB). In 2000 the cost of MB more than quadrupled making it exceedingly expensive for almond growers. Additionally, MB is planned for phase out in 2005. None of the pre-plant alternatives listed below exhibits flexibility of use, a hallmark of MB.

The closest alternative to methyl bromide is 1,3-D with trade names including Telone II (35 gal/acre), Telone C35. California registrations for these products are restricted by application rates (33.7 gal/acre of 1,3-D), township caps, buffer zones, and the requirement for surface moisture prior to application. Proper applications in California are essentially limited to coarser-textured soils and sites idled for at least one year in order to deeply dry the soil.

Chemical Control:

- **Chloropicrin** (Pic) - When applied at 330 lb/acre can control nematodes to five feet if soil is dried, does not appear to be as good at root penetration, but is one of the best growth stimulators of all the fumigants. There has been phytotoxicity when rainfall occurs soon after its application to moist, cool soil. This is a good material to manage the replant disorder.

- **Metam sodium** (MS) - and metam potassium sold as Vapam or K-pam have performance capability only when properly applied with high volumes of water (6+ acre-inches). Sprinkler delivery of this odorous product has presented problems to vegetable growers familiar with it so tree growers with less experience should be encouraged to deliver it by methods other than sprinkler. Peach root systems do not expand well into soil treated with MS. Almond growers should wait a full year between the MS application and eventual planting.

- **Sodium Tetrathiocarbonate (Enzone) -** Generates carbon bisulfide within soil. This general biocide is delivered at too low of concentrations to kill old roots. Enzone should not be used pre-plant unless old tree roots are already dead and the target pest is not within roots. It also should not be applied mid winter with the expectation of planting within 60 days.

The decision of whether to treat broadcast or in strips is dependent upon pest presence and the level of pest resistance in the new rootstock.

Root knot nematodes are primarily controlled with use of Nemaguard rootstock. Without resistance, warm sandy soil infested with root knot can result in first-year tree death.

Over the last forty years much of California's almond acreage was planted to lands not previously planted to tree or vine crops. Nemaguard is particularly sensitive to the rejection component of the replant problem. This malady can commonly reduce first-year tree growth of a replanted orchard to 15% of that of a fumigated comparison. Following the first spring and summer of apparent rejection by the soil; trees on Nemaguard resume growth but this may occur erratically across the field. Eventual tree establishment in the second year and beyond is dependent on incidence of soil pests and diseases as well as soil physical and chemical problems that should have been corrected prior to replanting.

Availability of Nemaguard does not reduce problems with root lesion nematode, *Pratylenchus vulnus*, ring nematode *Mesocriconema xenoplax* and in a few situations *Xiphinema americanum*. This latter nematode can be important specifically where there is concern about the virus it vectors, almond yellow bud mosaic.

Telone II applied in strips or applied to less-than-dry soils can solve the rejection component of the replant problem but strip treatments will not adequately protect against root lesion and ring nematodes. A proper application of fumigant can protect trees for 6 years or more whereas poor applications and strip applications commonly provide only one year of nematode relief. In the Sacramento Valley there is not a rejection component when planting peach roots after peach roots. Lovell rootstock happens to be the rootstock of choice in that region and root knot nematode is also not a problem in the Sacramento Valley.

There are no rootstocks providing resistance to *P. vulnus, M. xenoplax* or *X. americanum* and 33% of replanted almond orchards contain these nematodes. The time to control nematodes is pre-plant; however ring nematode can still present a problem within several years after planting.

Post-plant - Fenamiphos (Nemacur) has only been registered for use in non-bearing almonds. This OP compound is an effective nematicide but its registration for use in the US will be cancelled as of 2007.

Chemical Control:

- **Sodium Tetrathiocarbonate (Enzone)** - Liberates carbon bisulfide into soil which when carefully applied at 750 to 1000 ppm via drip reduces populations of ring and dagger nematodes by 60% for a 6-month period.

Cultural Control:

- **DiTera -** Is a mixture of toxins produced as a result of rearing *Myrothecium* fungus in large vats. This nematicidal agent is registered in California. Trees are slow to respond but this product is effective against all the nematodes of concern whenever they are outside of roots. Ditera is likely best for application in combination with other nematicidal agents and offers the opportunity to make summer-time treatments when Enzone should not be applied. Problem of reaching greater soil depths.

- Use of rootstocks with root knot nematode resistance.
- Use of certified nematode-free rootstocks.
- One year of fallow between replants.
- Monitoring with soil samples to properly diagnose problems.
- Use of low-volume and solid set irrigation methods that reduce damage.
- Selection of orchard sites that have not previously supported perennial crops.

Critical Needs for Management of Nematodes

Research:

- Search for resistance to ring nematode and root lesion nematode.
- Improve on the efficacy of Ditera.
- Study new post-plant nematicidal agents.
- Differentiate snake oils from real nematicidal agents.
- Learn more about almond bud drop and its connection to ring nematode.
- Commercial evaluations of the worth of Roundup applications for root kill.
- Research on Iodomethane as a MB alternative.

Regulatory:

- Orchards to be replanted to finer-textured soil need Telone II available at treatment rates as high as 67 gallons per acre. This could likely be justified by adjusting the current off-gassing model to finer-textured soil instead of just sandy loam soils.
- The requirement for surface moisture prior to Telone applications is almost unmanageable and delivery of too much deep water in the process can destroy the value of fumigation. Relief is needed here and an alternative would be to require deeper application depths (26 inches instead of 20 inches) in lieu of requiring high surface moisture.
- Relief of Telone cap regulation particularly in light of MB cancellation.
- Expedite the registration of iodomethane in CA.

Education:

- Develop and explain economic threshold values, the value of soil monitoring, and particularly monitoring prior to making pre-plant decisions.
- Educate the growers on use of metam sodium.
- Educate regulators on the practicality of metam buffer zones.

Vertebrate Pests

Ground Squirrels – are a major pest in almonds. Treat in the spring with aluminum phosphide. Baits are used from May through July.

Chemical control:

- **Zinc phosphide** - bait.
- **Anti-coagulants** - bait.
- **Aluminum phosphide** - fumigant.
- **Acrolein –** fumigant - Worker issues. Not used because of the method of application, worker issues.

Non-chemical

- **Rodex 4000 –** Propane oxygen injection device.
- **Kill Traps**.
- **Shooting**.

Pocket Gophers – Major problem because they are difficult to control especially in new orchards.

Chemical control

- **Strychnine** – Bait.
- **Anti-coagulants** – Bait – Efficacy not known.
- **Aluminum phosphide** – Fumigant.

Non-chemical

- **Rodex 4000**.
- **Traps**.
- **Barn owls** – Questionable efficacy.

Deer mice – Are a significant problem because they can carry the Hanta Virus.

Chemical control:

- **Anti coagulants –** can't use in endangered species habitats.

Rabbit – Jackrabbits and Cottontails are a problem in orchards that butt up against rangeland sites. They are mostly an issue for young trees.

Chemical control:

- **Anti-coagulants –** There are a lot of regulatory restrictions on the use. Cannot be used on cottontail rabbits.

Non-chemical controls:

- **Trunk protectors**.
- **Fences**.
- **Shooting**.

Crows

Non-chemical controls:

- **Frightening devices –** These are short-term solutions as crows become accustom to the noise.
- **Shooting -** Is a major option for crows.

Ravens

Non-chemical controls:
- **Frightening devices** – These are short-term solutions as crows become accustom to the noise.
- **Shooting** – Requires a permit from the US Fish and Wildlife Service.

Magpies, scrub jays

Non-chemical controls:
- **Frightening devices –** These are short-term solutions as crows become accustom to the noise.
- **Shooting –** Magpies can be shot without a permit. Scrub jays you would need a permit from the US Fish and Wildlife Service.

Turkeys – Emerging problem in foothill regions.

Non-chemical
- **Shooting –** Need a hunting permit.

Deer - Are a problem in young orchards and replanted trees in mature orchards.

Non-chemical controls:
- **Fencing -** Expensive.
- **Shooting –** Requires a permit from state Fish and Game Department.

Pigs - Are a problem in young orchards.

Non-chemical control:
- **Shooting –** Requires a permit from state Fish and Game Department.

Fox squirrel – Introduced species.

Non-chemical control:
- **Shooting**.

Voles - Voles are a problem if you are using a cover crop.

Chemical control:
- **Zinc Phosphide -** Bait.
- **Anti-coagulant -** Bait.

Coyotes - Damage drip lines.

Non-chemical control:
- **Shooting**.
- **Trapping**.

Critical needs for vertebrate control in almond orchards

Research:
- Control of rodents in the areas of endangered species.
- Alternatives for pocket gopher control.
- Biocontrol using predators such as owls.
- Bait acceptance relative to crop maturity.
- Control measures for exotic pest such as fox squirrels and rosewinged parakeet.
- Need to know more about vertebrate feces and what they are bringing into the orchards.
- Vectors for diseases.

Regulatory
- Rodenticide use in crops. Label clarifications.
- Better mapping of endangered species ranges and habitats.

Education
- Use of county bulletins on endangered species.
- Anti-coagulant resistant management.
- Better help to growers on long-term and continued strategy on how to control vertebrates.
- Integrated control of vertebrates (fumigants, baits, habitats etc.).

Postharvest Issues

After almonds are harvested, dried and hulled, they are shipped to a processing plant. There they are kept in bins, silos, or other means of bulk storage. At the time of delivery the processor will fumigate to kill insect pests coming in from the field. The primary field pests killed by fumigation are navel orangeworm, peach twig borer and ants. Almonds may remain in storage from several weeks to several months until they are further processed. Basic processing includes sorting to eliminate defects, insect or microbial damage and sorting by variety and/or size classification. Further manufacturing of the product may include roasting, blanching, slicing or dicing, salting or flavoring, and packaging.

While in storage, almonds are susceptible to insect damage. Of primary concern are Indian meal moth, almond moth, red flour beetle and saw tooth/merchant grain beetle. Fumigation is used to control storage pests. The most common post-harvest fumigation treatment in the almond industry is phosphine gas. Methyl bromide is sometimes used for fumigation, but usually only if required by the receiving customer/importing country or when the fumigation is necessary in a short time frame. Propylene oxide (PPO), sometimes used as a sterilant, also has insecticidal properties.

Thus the most critical postharvest issue in almonds is the need to maintain the use of phosphine as a fumigant. Methyl bromide, the most efficacious alternative product, is being phased out as an ozone-depleting substance. As of 2005 no use will be permitted except for exemptions and quarantine uses. Other possible alternatives such as freezing or irradiation also have significant limitations to their widespread use such as cost or consumer (especially export markets) acceptance.

- Aluminum Phosphide applied under tarp or to sealed silo prior to hulling and processing.

- Pyrethrins and DDVP are often used around the facility and in areas where processed almonds are stored to keep insect populations down that might infest the nuts.

Emerging Pests

Ten-lined June Beetle

The ten-lined June beetle is a very rare but serious pest and occurs in isolated spots with sandy ground. This pest is very difficult to control. It is 1 inch (2.5 cm) long when mature. There is one generation every 2 years and adults emerge from the soil from late June through August. Larvae feed on roots, causing severe injury and death to mature trees. Adults cause no damage. There are currently no registered materials for control of this pest after trees are planted. Control requires the removal of infested trees and soil fumigation before replanting. Determine the extent of the infestation by removing trees and inspecting roots for the presence of larvae or larval feeding. Remove all trees in the infested area plus one or two uninfested trees on all sides of the infested area. Fumigate the soil and replant following label directions. (www.ipm.ucdavis.edu)

Glassywinged Sharpshooter, *Homolodisca coagulata*

Glassywinged sharpshooter is potentially the most threatening pest to almond production. It is a xylem feeding leafhopper that carries the bacteria *Xylella fastidiosa* that causes almond leaf scorch. The same bacteria also causes Pierces Disease in grapes and alfalfa dwarf in alfalfa. Glassywinged sharpshooter has recently become established in Kern and Tulare counties and can be found in most of the almond growing counties of California. It is a strong flier and can travel far. Because of the devastating effect of almond leafscorch and the number of host plants where the disease resides, glassywinged sharpshooter must me controlled. Although systemic insecticides, such as imidacloprid, are effective, the insect must feed before the pesticide is ingested. This will allow for transmission of the bacteria. Also the cost of imidacloprid is quite high ($180 per acre). Contact insecticides are needed to manage this pest. These would include materials such as chlorpyrifos, phosmet, and carbaryl.

Trade Issues

California almonds are sold to approximately 80 different countries. Over 80% of California's production is exported. Historically, the primary trade barriers have been related to tariff level and market access issues such as import quotas and licensing. In addition, phytosanitary concerns such as contaminants are also increasing. The industry has implemented a number of Good Agricultural Practices (GAPs) and Good Manufacturing Practices (GMPs) to assure consumer confidence in food safety.

Trade issues, with respect to pest management, are becoming increasingly important to almond buyers and sellers. Country-by-country variances in residue level limits and tolerances are forefront to these concerns. Due to careful and highly regulated production and application practices, pesticide residues in almonds are infrequent. Dormant sprays are applied when there is no product on the tree. If used in-season, the almond kernel is protected from applications by both a hull and a shell. Nevertheless, international customers are now more likely to request information about how, when and where pesticides and fungicides are applied to almonds. Out-going shipping inspections and port-of-entry testing are tools used insure customer confidence.

References

1. California Department of Pesticide Registration Pesticide Use Database (1999 – 2001)
2. Almond Crop Profile (1998)
3. UC IPM Pesticide Guideline for Almonds (2001)

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Table 1

Insect Pest Management Tools: *Registered Materials*	Navel Orangeworm	Peach Twig Borer	Ants, (Pavement, So. Fire)	European Red Mite	Brown Almond Mite	San Jose Scale	Peach Silver Mite	Peachtree Borer	American Plum Borer	Leaffooted Bug	Oblique-banded Leafroller	Oriental Fruit Moth	Shothole Borer	Pacific Flatheaded Borer	Fruittree Leafroller	Ten-lined June Beetle	Webspinning Spider Mites	Forest Tent Caterpillar	Leafhoppters	Grasshoppers	False Chinch Bug	Earwigs	Glassy Winged Sharpshooter	Cucumber Beetle	Thrips
Chemical/Trade Name																									
Avermectin (Clinch)			F-E																						
Avermectin (Agri-Mek)				?	?		G-E										G-E		G				?		G
Azinphos-methyl (Guthion)	G	G	U			U			U	G	F-G	F-G			G			G	G	G	G	G	U	G	G
Bt (Dipel)	P-F	F									F	P-F			F			F-G							
Carbaryl (Sevin)	F-G	F-G				F			F-G	F	F	F-G	?	?	F-G	?		G	G	G		G	G		
Chlorpyrifos (Lorsban)	G	E-G	G-E			F-G		G	G	G	E	G			G	?		G	G	G		G	U	G	G
Clofentezine (Apollo)				G	G		?										F-G								
Diazinon (dormant)		E-G	G			P-G			F		U				U									?	
Dormant Oils				G	G	F-G	G																		
Esfenvalerate (Asana)	G	E-G				F-G		?	?	G	F	G	U	U	F-G	?		G	E	?	?	U		?	?
Fenbutatin-oxide (Vendex)				P-G	P-G		G										F-G								
Malathion	P	F	P-F	P-F	P-F	P-F												?	F	G	G	U		G	U
Methidathion (Supracide)		G-E		P-F	P-F	F-G				?	?	?			?			?	G						
Naled (dormant)		F-G				?					U				U				G						
In-season oils	U			G	G	F-G	G										F-G		F-G						U
Permethrin (Ambush/Pounce)	G	F-G	P			?		?		G	P-F	G			G			G	?	F-G	G	U		?	?
Phosmet (Imidan)	F-G	F	F			F		U	U	F	F	F-G			F-G			G	G	U	G	?			
Propargite (Omite)				G	G		G										P-E		G				U		
Pyriproxyfen (Knack)		P	G-E			E													?						
Spinosad (Success)	P-F	G	P						?		E	G			G			?	?	?					G
Sulfur				U	U		E										U								

Efficacy rating symbols: E = Excellent, G = Good, F = Fair, P = Poor, ? = No data but suspected of being efficacious, blank = not used and not suspected of being efficacious, res = some resistance in pest population. U = Unknown, NE = Not Efficacious

Table 2

Insect Pest Management Tools:	Navel Orangeworm	Peach Twig Borer	Ants, (Pavement, So. Fire)	European Red Mite	Brown Almond Mite	San Jose Scale	Peach Silver Mite	Peachtree Borer	American Plum Borer	Leaffooted Bug	Oblique-banded Leafroller	Oriental Fruit Moth	Shothole Borer	Pacific Flatheaded Borer	Fruittree Leafroller	Ten-lined June Beetle	Webspinning Spider Mites	Forest Tent Caterpillar	Leafhoppters	Grasshoppers	False Chinch Bug	Earwigs	Glassy Winged Sharpshooter	Cucumber Beetle	Thrips
Non-chemical Aids																									
Dust control				Y		?											Y								
Early harvest	Y																								
Fumigation-pre-hulling	Y	Y	Y									Y													
Latex paint								Y	Y				Y	Y											
Orchard sanitation	Y																								
Removal of infested plant parts													Y	Y											
Parasites	Y	?				Y				Y	?					?		Y	?						
Pheromones-monitoring	?	Y				Y			Y		Y	Y			?	?									
Pheromones-mating disruption	?	Y									Y	Y													
Predators	?	Y		Y	?		?										Y								?
Egg traps	Y																								
Garlic Juice (Allityn)																									

Rating scale: Y = yes; blank = N; ? = research needed;

Table 3

Pest Management Tools: ***Unregistered Potential Alternatives***

Chemical/Trade Name	Shothole	Scab	Hull rot	Fruit rot	Anthracnose	European Red Mite	Brown Almond Mite	Peach Silver Mite	Webspinning Spider Mites	Ants	Nutsedge	Broadleaves	Grasses	Navel Orangeworm	Brown rot	Comments
BAS 516	X	X	X	X	X											
Bifenazate						Y	Y	Y								At EPA – 9/02
Emamectin benzoate														?		IR-4 PCR needed
Ethephon (PGR)																
Fipronil										X						
Flumioxazin (Chateau)												Y	Y			Extended preemergence control of broadleaves and grasses including fleabane, filaree, puncturevine, purslane, and spurge.
NAA (PGR)																
Pendimethalin (Prowl) (bearing)													Y			Season-long control or suppression of sprangletop and many other annual grasses. Effective at helping to eliminate johnsongrass and suppresses bindweed. At EPA since 3/01. Risk cup full.
Propylene oxide														X		Mfg. submitted to EPA – MB alternative
Tebuconazole (Elite)					X										X	
T & V (bearing)												X				
Thiazopyr (Visor)											X	X	X			Good control of nutsedge. Good suppression of spurge, marestail and fleabane. High cost of material may dictate actual use. IR-4 PCR needed.

Rating scale: X = activity; ? = believe efficacious but need research

Table 4

Disease Pest Management Tools: *Registered Materials*

Chemical/Trade Name	Brown rot	Anthracnose	Shot Hole	Scab	Leaf Rust	Bacterial Canker	Crown Gall	Root & Crown Rot	Verticillium wilt	Armillaria Root rot			Alternaria Leaf spot	Leaf Blight	Comments
1,3 Dichloropropene (Telone)						G			P						Good control as long as application conditions are correct.
1,3 Dichloropropene (Telone C35)						G			G						Good control as long as application conditions are correct.
Agrobacterium Radiobacter-84#							G								At planting
Azoxystrobin(Abound)	G	G	G	G	E								E	G	
Captan	G	F	E	G										G	
Copper			?												
Cyprodinil (Vangard)	E														
Fenhexamid (Elevate)															New Registration
Fosetyl-Al (Aliette)								F							Non-bearing only
Gallex							G								
Iprodione (Rovral)	E		G												
Maneb	P	F	G	G	G										
Mefenoxam (Ridomil Gold)						?		G							
Methyl Bromide + Chloropicrin						E		E	E	E					
Metam-Sodium						P			?						
Myclobutanil (Laredo)	E	F	F												
Sodium Tetrathiocarbonate (Enzone)						F				U					
Sulfur				G	G										
Thiophanate-methyl (Topsin M)	E			G											
Trifloxystrobin (Flint)	G	E	G	G	E								E		
Ziram		F	E	G										G	

Efficacy rating symbols: E = Excellent, G = Good, F = Fair, P = Poor, ? = No data but suspected of being efficacious, blank = not used and not suspected of being efficacious, res = some resistance in pest population. U = Unknown, NE = Not Efficacious

Table 5

Disease **Pest Management** ***Cultural/Non-chemical Aids***	Brown rot	Anthracnose	Shot Hole	Scab	Leaf Rust	Bacterial Canker	Crown Gall	Root & Crown Rot	Verticillium wilt	Armillaria Root rot	Almond Leaf Scorch	Alternaria Leaf spot
Pruning	Y	Y									Y	
Irrigation management		Y	Y	Y		Y		Y	Y	Y		Y
Natural enemies												
Mummy removal		Y										
Weed control												
Sucker removal												
Cover crops												
Discing												
Sanitation							Y			Y		
Nutrition	Y			Y		Y						
Rootstock selection								Y		Y		
Tree removal											Y	

The Y (Yes) and N (No) designation regarding non-chemical options refer to whether the non-chemical aid is used as a toll against a specific pest.

Table 6

Beneficials

Chemical Names	Copidosoma plethorica	Goniozus legreri	Chalcid wasps	Western Predatory Mite	Sixspotted thrips	Spider mite destroyer	Brown Lacewings	Green Lacewings	Twice Stabbed Lady Beetle	Chbocephalus californicus	Aphelinid wasps	Comments
Abemectin (AgriMek)	U	U	U	M	?	U	L	L	U	U	U	
Avermectin (Clinch)	O	O	O	O	O	O	O	O	O	O	O	
Azadirachtin (Ecozin)				L-M	M	U	?	?	U			
Azinphosmethyl (Guthion)	?	?	?	L-M	M-H	U	?	?	?	?	?	
Bt (Dipel)	O	O	O	O	O	O	O	O	O	O	O	
Buprofezin (Applaud)				U		?			?			
Carbaryl (Sevin)	?	?	?	H	?	?	?	?	M	?	?	
Chlorpyrifos (Lorsban)	?	?	?	M-H	?	?	?	?	M	?	?	
Clofentezine (Apollo)				O	U		O	O				
Dormant Oils				O								
Esfenvalerate (Asana)	?	?	?	M-H	?	?	H	H	?	?	?	
Fenbutatin-oxide (Vendex)				L	?							
Hexythiazox (Savey)				O	U	O	O	O	O			
Kaolin (Surround)				?	?	U	U	U	U			
Malathion	?	?	?	L-M	?	U	U	U	?	?	?	
Methidathion (Supracide)				?	?							
In-season oils				L	L	L	L	L				
Permethrin (Ambush/Pounce)	?	?	?	M-H	?	?	H	H	?	?	?	
Phosmet (Imidan)	?	?	?	L-M	?	U	U	U	?	?	?	
Propargite (Omite)				L	?		U	U				
Pyrethrins				L-M	L-M							
Pyridaben (Nexter/Pyramite)				H	?	U	M	M	U			
Pyriproxyfen (Esteem)					U	?	U	U	H			
Spinosad (Success)				U	?	U	U	U	U			
Sulfur				M-H	M	U	U	U	U			
Tebufenozide (Confirm)						U	U	U	U			

H=highly toxic; M=Moderately toxic; L=Low toxicity; O=No toxicity; U=Unknown (research needed); ?=Suspected of being toxic; research needed

Table 7

Nematode Pest Management Tools:[1]	Root knot nematode	Root knot nematode	Root lesion nematode	Root lesion nematode	Ring nematode	Ring nematode	Dagger nematode	Dagger nematode																	
Chemical name	Pre	Post	Pre	Post	Pre	Post	Pre	Post																	
1,3-D (Telone)	E		E		E		E																		
Ditera (biopesticide)		P		F		F		F																	
Metam sodium (Vapam)	G		G		G		G																		
Methyl Bromide	E		E		E		E																		
Sodium tetrathiocarbonate		P		P		G		G																	
Cultural/Non-chemical[2]																									
Fallow (1 year)	Y/N		Y/N		Y/N		Y/N																		
Fallow (2-3 years)	N		N		N		N																		
Monitoring-soil samples	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N																	
Soil/water/nutrient management		N		Y		Y		N																	
Resistant rootstocks	Y	Y	NA		NA		NA																		

[1]E = Excellent, G = Good, F = Fair, P = Poor, ? = No data but suspected of being efficacious, blank = not used and not suspected of being efficacious, res = some resistance in pest population. U = Unknown, NR = Not registered

[2] The Y (Yes) and N (No) designation regarding non-chemical options refer to whether the non-chemical aid is used as a tool against a specific pest, ? = No data but suspected of being efficacious, blank = not used and not suspected of being efficacious.

Table 8

Vertebrate Pest Management Tools:[1]	Ground squirrels	Pocket gophers	Deer mice	Rabbit	Crow	Raven	Magpies, scrub jays	Turkeys	Deer	Pigs	Fox squirrel	Voles													
Legal Restrictions	0	0	0	0	1	2	3	3	3	3	1	0													
Cultural and Non-chemical																									
Frightening methods	-	-	-	-	+	+	+	-	-	-	-	-													
Recorded distress calls	-	-	-	-	+	-	-	-	-	-	-	-													
Weed control	-	=	+	+	-	-	-	-	-	-	-	+													
Cover crops	-	=	-	-	-	-	-	-	-	-	-	=													
Traps	+	+	-	-	=	-	-	-	-	-	+	-													
Rodex 4000	=	=	-	-	-	-	-	-	-	-	-	-													
Rodenticides/ repellent																									
Anticoagulant bait	+	-	+	-	-	-	-	-	-	-	-	+													
Zinc phosphide	+	?	-	?	-	-	-	-	-	-	-	+													
Strychnine	-	+	-	-	-	-	-	-	-	-	-	-													
Aluminum phosphide	+	+	-	-	-	-	-	-	-	-	-	=													
Acrolein fumigant	+	-	-	-	-	-	-	-	-	-	-	-													
Deer Away repellent	-	-	-	-	-	-	-	-	=	-	-	-													

[1]0 = control in any manner
1 = Authorized if damaging or threatening crop or property
2 = Permit required from US Fish and Wildlife Service
3 = Permit required from California Department of Fish and Game

- = not registered and/or not effective
0 = not tested but likely ineffective
= = may be effective or reduce occurrence of pest
+ = registered and/or considered effective

Table 9

Worker Activities Table

Worker Activity	January	February	March	April	May	June	July	August	September	October	November	December	Comments
Mummy removal	■											■	This activity is done by shakers or knocking them off by long poles.
Pruning	▒			▒	▒	▒	▒	▒	▒	▒		▒	This activity could start in Mid-March.
Brush removal	■											■	
Herbicide application	▒			▒	▒	▒	▒	▒	▒	▒		▒	This activity could start in Mid-March
Irrigation	■	■	■	■	■	■	■	■	■	■		■	This activity could start in Mid-February
Fertilizer	▒			▒	▒	▒	▒	▒	▒	▒		▒	
Insecticide application	■	■	■	■	■	■	■					■	
Mowing		▒	▒	▒	▒	▒	▒	▒	▒	▒			
Monitoring		■	■	■	■	■	■	■	■	■			
Hull split spray							▒						
Harvesting								■	■	■			Can range between Mid-July to Mid-November depending on location and variety.

Three-Year Usage Table 1999 – 2001

Table 10

Common Chemical Name	1999 % Ac Treated	1999 Base Ac Treated	1999 Total Lbs AI	2000 % Ac Treated	2000 Base Ac Treated	2000 Total Lbs AI	2001 % Ac Treated	2001 Base Ac Treated	2001 Total Lbs AI
2,4-D	11%	62,371	55,835	12%	72,235	64,880	11%	65,966	58,554
Ammonium Sulfate	4%	21,547	9,281	4%	24,294	6,499	4%	25,953	12,492
Avermectin	15%	86,851	733	25%	146,395	1,138	27%	159,112	1,277
Azinphosmethyl	10%	56,271	105,916	8%	46,140	83,656	9%	50,036	87,821
Azoxystrobin	5%	26,316	7,931	23%	139,767	32,853	15%	87,235	19,053
Bacillus Thuringiensis	13%	77,553	9,173	15%	90,063	11,723	9%	54,851	5,819
Benomyl	10%	57,013	31,736	8%	45,775	26,269	3%	16,726	8,680
Captan	26%	148,807	554,468	16%	98,159	299,375	7%	42,392	108,516
Carbaryl	1%	4,664	14,327	1%	3,878	11,882	0%	2,250	3,899
Chlorpyrifos	19%	113,135	209,636	21%	124,850	235,879	15%	86,601	162,846
Copper	26%	153,669	706,823	18%	109,767	437,250	15%	87,959	363,250
Cyprodinil	9%	54,853	13,706	23%	138,632	37,342	24%	137,810	32,822
Diazinon	10%	58,883	125,342	5%	27,041	64,948	5%	31,345	63,197
Esfenvalerate	18%	103,472	5,484	15%	89,936	4,250	17%	96,207	5,113
Fenbutatin-oxide	6%	36,135	24,035	4%	23,958	14,848	5%	27,232	22,364
Glyphosate	65%	378,716	698,595	64%	381,633	658,440	63%	362,425	637,544
Iprodione	42%	241,239	134,044	49%	289,288	165,994	38%	219,710	121,108
Maneb	13%	76,612	277,049	10%	58,146	181,448	5%	29,531	89,624
Methidathion	6%	35,762	52,820	3%	19,330	25,120	3%	17,020	23,105
Methyl Broimide	3%	14,691	357,016	1%	8,672	151,199	1%	7,270	38,964
Mineral Oil	12%	70,851	2,065,763	9%	53,030	1,549,322	11%	63,094	1,453,070
Myclobutanil	3%	19,304	2,783	6%	37,430	4,912	13%	73,688	12,662
Naled	0%	730	2,332	0%	247	497	0%	39	32
Norflurazon	8%	45,871	49,749	10%	58,566	54,833	9%	49,784	46,106
Oryzalin	15%	85,892	170,030	7%	42,174	69,412	1%	5,454	6,042
Oxyfluorfen	42%	246,285	101,301	44%	260,119	77,878	41%	237,862	50,988
Paraquat	26%	153,733	164,330	24%	144,780	168,813	22%	128,493	122,723
Pendimethalin	2%	13,556	23,672	2%	12,274	20,101	1%	8,150	15,648
Permethrin	16%	95,335	21,181	17%	103,183	19,979	16%	94,309	22,877
Petroleum Oil	37%	212,396	6,439,852	34%	200,897	6,246,656	30%	173,237	4,363,639
Phosmet	7%	42,997	142,783	8%	43,438	194,100	5%	31,021	98,204
Propargite	31%	181,805	415,205	25%	147,633	306,366	29%	167,134	388,324
Propiconazole	20%	115,337	21,133	0%	200	20	0%	251	48
Simazine	14%	81,441	55,832	16%	93,434	62,236	13%	76,599	51,777
Soybean Oil	0%	1,860	22,533	0%	1,307	14,168	0%	1,615	9,837
Spinosad	7%	40,611	4,404	6%	37,723	3,863	3%	17,249	1,813
Sulfur	3%	15,285	177,998	3%	19,864	187,988	2%	14,307	123,452
Tebufenozide							3%	19,978	5,693
Thiophanate-methyl	6%	32,605	25,482	5%	27,850	22,663	4%	21,743	15,784
Trifluralin	2%	13,653	18,059	2%	13,448	13,225	4%	21,270	19,911
Zinc Sulfate	3%	17,233	2,308	3%	17,013	2,249	2%	12,417	2,007
Ziram	20%	115,685	657,129	17%	99,663	567,538	13%	76,371	396,435

Table 11 Weed Pest Management *Registered Materials:* Broadleaf Weeds C=Control P=Partial control	EPTC (Eptam®)	Isoxaben (Gallery T&V®) - NB	Napropamide (Devrinol®)	Norflurazon (Solicam®)	Oryzalin (Surflan®, Oryzalin® - NB)	Oxyfluorfen (Goal®)	Pendimethalin (Prow®, etc.) - NB	Simazine (Princep®)	Thiazopyr (Visor®) - NB	Trifluralin (Treflan®, etc.)	Clethodim (Prism®) - NB	Diquat dibromide (Reglone®) - NB	Fluazifop - p (Fusilade DX®) - NB	Glufosinate (Rely®)	Glyphosate (Roundup Ultra®, etc.)	Halosulfuron (Sempra CA®)	MSMA (Bueno 6®, etc.) - NB	Paraquat (Gramoxone Max®)	Sethoxydim (Poast®)	Sulfosate (Touchdown 5®)	2,4-D amine (Various trade names)
A. morningglory		C	P	C	P	C		C				P		C	C	P	P	P		C	C
Cheeseweed		C	P	P		C	P	P	C			C		C	P			C		P	C
Chickweed	C	C	C	P	C	P	C	C	C	C		C		C	C		C	C		C	C
Clovers		P	P			P		C				P		P	P			P		P	
Cocklebur			P	C		P		C				C		P	C	C	P	C		C	C
Cudweed	P	C	C	C				C				C		P	C			C		P	
Fiddleneck	C	C	C	P	C	C	C	C		C		C		P	C			C		C	P
Filaree	C	C	C	P	P	C		C		P		C		C	P			P		C	
Goosefoot	C	C	C	P	C	C	C	C	C	C		C		P	C			C		C	C
Groundcherry	C	C		C		C		C	P	P		C		C	C		P	C		C	P
Groundsel	C	C	P	P		C		P	C			C		P	C			C		C	P
Hairy fleabane	C	C		P		P		C	P			P		C	C			P		C	C
Henbit	C	C		P	C	C	C	C	P	P		C		C	P			C		C	C
Knotweed	P	C	C	P	C	P	C	C	C	C		P		P	P			P		P	C
Lambsquarters	C	C	C	P	C	C	C	C	C	C		C		P	C	P		P		C	C
London rocket	P	C	C	P		C	P	C				C		C	C			C		C	
Marestail	C	C		P		P		C	P			C		C	C			P		C	P
Miners lettuce	P	C	C	C	C	C	C	C	C	C		C		C	C			C		C	C
Mustard		C	P	P		C	P	C				C		C	C	C		C		C	C
Nettle	C	C	P	C	P	C		C				P		C				C			C
Nightshade		C		C		C		C				C		C	C			C		C	C
Pigweed	C	C	C	P	C	C	C	C	C	C		C		C	C	C		C		C	
Pineappleweed	P	C	P	P		C		C				C		P	C			P		C	
Prickly lettuce	C	C	C	P		C		C				C		C	C			P		C	C
Puncturevine		C	P	C	P	P	P	P	P	P		C		P	C		P	C		C	C
Purslane	C	C	C	C	C	C	C	C	C	C		C		C	C		P	C		C	P
Red maids	C			C	C	C	C	C	C	C		C		C	C		P	C		C	P
Russian thistle	P	C	P	C	P	P	P	C	P	P		P		C	C			P		P	P
Shepherdspurse	P	C	P	P		C	P	C	C			C		C	C			C		C	C
Sowthistle	C	C	C	P		C		C	C			C		C	C			C		C	C
Speedwell		C		P	P	P	P	P	P	P		C		C	C			C		C	C
Spurge		C	C	C	P	C	P	P		P		C		C	C			C		C	
Wild radish		C	P	P		C		C	C			C		C	C			C		C	C

Weed Pest Management Tools: ***Registered Materials:*** **Other Weeds** C=Control P=Partial control	EPTC (Eptam®)	Isoxaben (Gallery T&V®) - NB	Napropamide (Devrinol®)	Norflurazon (Solicam®)	Oryzalin (Surflan®, Oryzalin® - NB)	Oxyfluorfen (Goal®)	Pendimethalin (Prowl®, etc.) - NB	Simazine (Princep®)	Thiazopyr (Visor®) - NB	Trifluralin (Treflan®, etc.)	Clethodim (Prism®) - NB	Diquat dibromide (Reglone®) - NB	Fluazifop - p (Fusilade DX®) - NB	Glufosinate (Rely®)	Glyphosate (Roundup Ultra®, etc.)	Halosulfuron (Sempra CA®)	MSMA (Bueno 6®, etc.) - NB	Paraquat (Gramoxone Max®)	Sethoxydim (Poast®)	Sulfosate (Touchdown 5®)	2,4-D amine (Various trade names)
Annual bluegrass	C		C	C	C	P	C	C	C	C	C	P		C	C			C		C	
Barnyardgrass	C		C	P	C	P	C	P	C	C	C	P	C	C	C		P	P	C	C	
Bromegrass	C		C	C	C	P	C		C	C	P		P		C			C	P	C	
Canarygrass	C		C	C	C	P	C	P	C	C	C	P	C	C	C			C	C	C	
Crabgrass	C		C	P	C		C		C	C	C	C	C	C	C		C	C	C	C	
Fescues	C		C	C	C		C	P	P	C	P	C	P	P	C			C	P	C	
Foxtail	C		C	P	C		C	C	C	C	C	P	C	C	C			P	C	C	
Junglerice	C		C	P	C	P	C	P	C	C	C	P	C	C	C			P	C	C	
Lovegrass	C		C	P	C	C	C	P	P	C	C	P	C	C	C			C	C	C	
Rabbitfootgrass	C		C	C	C	P	C	P	C	C	C	C	C		C			C	C	C	
Ryegrass	C		C	C	C		C	P	C	C	C	P	C	C	C			C	C	C	
Sandbur	C		C	C	C		C		C	C	C	P	C	C	C			P	C	C	
Sprangletop	C		C	P	P		P		C	C	C		C		C			P	C	C	
Wild barley	C		C	C	C	P	C	P	C	C	C	P	C	C	C			C	C	C	
Wild oats	C		C	C	P	P	P	C	P	P	P	P	C	C	C			C	C	C	
Witchgrass	C		C	P	C	P	C		P	C	C	P	P		C			C	P	C	
Bermudagrass - S	C		C	C	C	P	C	P	C	C	C	P	C	C	C			C	C	C	
Bermudagrass - E				P		P					C*		C*	P	C*				C*	C*	
Dallisgrass - S	C		C	C	C	P	C	C	C	C	C	P	C	C	C		C	C	C	C	
Dallisgrass - E				P		P					C*		C*	P	C*		C		C*	C*	
Johnsongrass - S	P		C	C	C	P	C	C	C	C	C	P	C	C	C		C	C	C	C	
Johnsongrass - E				C		P	P		P	P	C*		C*	P	C*				C*	C*	
Field bindweed - S				P	P	P	P	P	P	P		P		C	C			C		C	C
Field bindweed - E							P		P	P		P		P	P			P		P	P
Nutsedge, purple	P								P			P		P	C	C		C		C	
Nutsedge, yellow	C			P					C			P		P	C	C		C		C	