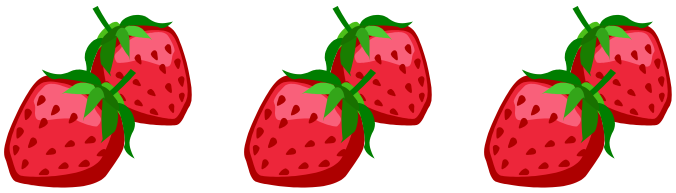
A Pest Management Strategic Plan for Strawberry Production in California



The California Strawberry Commission (CSC)

The California Minor Crops Council (CMCC)

The California Minor Crops Council (CMCC) received funding for this project from the EPA Region 9 Agricultural Initiative and the USDA Cooperative States Research, Education, and Extension Service (CSREES) Pest Management Alternatives Program (PMAP). CMCC received additional support from the California Strawberry Commission and the Western Regional Pest Management Center at UC Davis.

Funding for this project also has been made available by the Governor's *Buy California* initiative, the California Department of Food and Agriculture, and the U.S. Department of Agriculture, through the University of California's Specialty Crops Research Program.

We gratefully acknowledge the contributions of all of these organizations and their participation in this process.

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Introduction

California is the major state for strawberry production in the U.S., accounting for over 80% of the fresh market product grown in this country, on just over 50% of the national acreage. California strawberries are also an important component of international production; this state grows over 20% of the world's strawberry supply.

California has several geographical areas that are ideally suited to strawberry production. This, in combination with the availability of excellent horticultural information and pest management techniques, has enabled growers to produce almost four times the amount of fruit per acre as do other states in the U.S. There are approximately 28,000 harvested acres of strawberries in California, with up to 49,000 pounds of fruit produced on each acre. This yield is almost double that of Florida, which ranks as the second most important strawberry producing state in the U.S.

Strawberries are among the most challenging horticultural crops to grow due to the multitude and complexity of pest issues that growers must manage. Chemical usage, particularly for insect, mite, and disease control, has been a critical component in maintaining crop yield and the quality standards dictated by the domestic and international marketplace. A high level of pest pressure and a lack of research is probably what limits the current organic acreage of California strawberries to less than 2% of commercial production (although this acreage is increasing). For many years, intensive research has concentrated on pest management in strawberries in California. A highly productive relationship between the California strawberry industry and land grant partners (University of California and USDA-ARS) has resulted in the adoption of a highly effective system of integrated pest management (IPM) for this commodity.

The widely adopted system of integrated pest management (IPM) in strawberries relies on methyl bromide, an extremely effective pre-plant soil fumigant, as the cornerstone tool to manage a wide variety of insect, mite, nematode, weed, and disease pests. Virtually all pest management activities in strawberries have been predicated upon the establishment of a clean crop planted into fumigated soil. However, the Montreal Protocol, an international treaty, requires that methyl bromide production be phased out over the next several years. Additionally, new safety standards set forth by the 1996 Food Quality Protection Act (FQPA) have significantly impacted the availability and/or use patterns of important crop protection chemicals used by strawberry growers, especially organophosphate and carbamate insecticides/miticides. Therefore, the industry is working diligently with its state and federal partners to evaluate, register, and implement reduced risk production practices.

To help transition to "Reduced Risk" pest management in accordance with FQPA, the Montreal Protocol, and other regulatory activities, the USDA and EPA have requested that all commodities develop Pest Management Strategic Plans (PMSPs) to identify growers' critical research, registration, and educational needs. "Reduced Risk" broadly describes pest management techniques and tools that have low inherent toxicities and minimal impact on the environment. Pest management practices and products should be safe for both consumers and field workers, and crop protection tactics should have little or no impact on air, soil, or water quality.

The California strawberry industry has been evaluating its current pest management system to provide for a smooth transition to the new reduced risk chemical and non-chemical practices. In 2002, several key members of the strawberry industry met to focus specifically on the needs of California growers, and to develop a pest management strategic plan (PMSP) for the issues of greatest concern to all strawberry growers in California. A work group consisting of growers, packers, shippers, processors, Pest Control Advisers (PCAs), Farm Advisors, and researchers was formed to evaluate managing all types of strawberry pests, including insects, mites, diseases, weeds, and vertebrates. The work group also included representatives from the United States Department of Agriculture, the Environmental Protection Agency, Western Region IR-4, and the Western Region Integrated Pest Management Center.

These stakeholders provided an important perspective on the pesticides and alternatives used in the integrated pest management programs in the state. Focusing on the pests that have the greatest economic impact on the California strawberry industry, the work group produced a PMSP that identifies the critical research, regulatory, and educational needs of California strawberry growers. The foundation for this PMSP is the *Integrated Pest Management for Strawberries, 1994* (UC Publication 3351), and the *Crop Profile for California Strawberries, October 1999* (http://pestdata.ncsu.edu/cropprofiles/docs/castrawberries.html). Current cropping patterns, pest occurrences, and pest control strategies used in the various production areas are provided for the major production regions in California.

The California strawberry industry intends that this document be used as a resource by US EPA, USDA, CDPR and other agencies concerned with pest management issues, needs, and practices in California; this strategic plan will be periodically updated to remain current with industry developments and issues. Individual growers, pest control advisors, industry representatives, and university research and extension personnel are listed in the Appendices for those seeking more detailed input on strawberry production and pest management in California.

The use of product names in this document do not represent an endorsement of any particular trade or brand by any member of the Strawberry Work Group. For reference, chemical names and accompanying trade names are listed in the Appendices according to product type (insecticide, fungicide, etc.).

Stakeholder Recommendations

As a result of the PMSP planning meeting held in June 2002 and additional input received in 2003, the Strawberry Work Group identified the following research, regulatory, and educational priorities. These critical areas must be addressed to maintain the economic viability of the strawberry industry in California.

Research Priorities

Finding effective alternatives to methyl bromide is the most immediate and serious concern of California strawberry growers. Developing new products and management techniques for mites, lygus bugs, whiteflies, and two-spotted spider mites is the most pressing need for insect and mite control. Research on strawberry diseases should focus on powdery mildew and *Colletotrichum*. Conducting plant breeding work and improving nursery and plant management techniques for both conventional and organic growers will help to maintain this industry which is faced with the loss or restriction of various crop protection tools. University research and extension programs, critical to identifying and adopting new technologies for pest management in California strawberry production, should be supported on a continued basis by the appropriate local, state, and federal agencies.

- Develop new methods to produce clean nursery stock
- Evaluate iodomethane and other alternatives to methyl bromide
- Conduct long-term research on alternatives to fumigants in production fields
- Conduct long-term research on alternatives to fumigants in high and low elevation nurseries
- Evaluate new materials for in-season whitefly control
- Evaluate new materials and techniques to manage lygus
- Develop a resistance management strategy for spider mites
- Develop and evaluate herbicides for use under plastic mulches
- Evaluate new materials for control of powdery mildew
- Study the biology and epidemiology of *Colletotrichum*
- Evaluate soil and root microbiology on nursery stock and determine their impact on transplant performance
- Develop improved pest management and crop production methodologies for organic growers
- Continue plant breeding projects to improve horticultural and pest resistance characteristics of strawberries for organic and non-organic production systems

Regulatory Priorities

The strawberry industry seeks regulatory relief through a critical use exemption (CUE) for the continued use of methyl bromide until new alternative fumigants are registered by US EPA and CDPR. New registrations are needed for products to control mites, whiteflies, soil insects, and weeds. More harmonization between Cal/EPA and US EPA is needed to facilitate timely registration of reduced risk products; the IR-4 program should be used efficiently to identify good product candidates for research and registration. Registrants, regulatory agencies, and commodity groups should coordinate efforts to ensure that all new products comply with international regulations.

- Obtain a Critical Use Exemption (CUE) for methyl bromide
- Register alternatives to methyl bromide
- Obtain an Experimental Use Permit (EUP) for iodomethane
- Work with CDPR to develop relief for township caps for 1,3-D
- Harmonize international tolerances and MRLs
- Harmonize fumigant permit conditions among California counties
- Reduce carbaryl bait PHI
- Register materials for lygus, whiteflies, and powdery mildew
- Register organophosphate and carbamate alternatives as soon as possible; utilize the IR-4 priority system for research on reduced risk materials
- Harmonize Cal/EPA and US EPA registrations to hasten new product registrations
- Develop best management practices (BMPs) and environmental mitigation measures for environmental issues
- Identify potential trade irritants as early as possible in the research and registration process; insure there are no conflicts with provisions of NAFTA or Codex

Educational Priorities

The public, including regulators and consumer groups, must be educated about the use of Integrated Pest Management (IPM) in California strawberry production, and how this system optimizes food production while minimizing risks to workers and the environment. Growers need to be educated on new materials (especially methyl bromide alternatives), resistance management, and the most efficient and environmentally safe manner in which pesticides can be applied. All stakeholders need to be educated on agricultural practices and food safety. The regulatory community needs to be educated on the value and role of methyl bromide in the IPM system used in strawberries and how equally effective replacements will be needed to maintain production and quality standards currently established for domestic and international markets. Finally, consumers should be reminded that eating California strawberries is an important part of a healthy lifestyle and that this produce is grown under the highest standards of safety and quality in the world.

- Educate growers and PCAs on methyl bromide alternatives
- Educate the public and regulators on the need for fungicides
- Educate growers and regulators on resistance management
- Educate regulators on systems approaches to using fumigants such as methyl bromide on strawberries
- Educate applicators/growers on safe and efficient application techniques
- Educate growers, PCAs, and commodity members on the use of best management practices (BMP) to protect and improve water and soil quality
- Educate the urban and agricultural communities on good agricultural practices (GAPs) for food safety issues
- Educate the public on the nutritional values of California grown strawberries and their high level of food safety and quality

The California strawberry industry appreciates the support of US EPA, USDA, CDPR, and the University of California Land Grant system in this PMSP development process. We look forward to the valuable assistance provided by these agencies and institutions as we develop responses to the many issues facing the California strawberry industry.

The California Minor Crops Council (CMCC) received funding for this project from the EPA Region 9 Agricultural Initiative and the USDA Cooperative States Research, Education, and Extension Service (CSREES) Pest Management Alternatives Program (PMAP). CMCC received additional support from the California Strawberry Commission and the Western Regional Pest Management Center at UC Davis.

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December 2003

A PEST MANAGEMENT STRATEGIC PLAN FOR CALIFORNIA STRAWBERRIES

1. STRAWBERRY PRODUCTION OVERVIEW

Data from the USDA Economic Research Service show that strawberries are the fourth most valuable fruit crop produced in the United States (following grapes, apples, and oranges), and are second in value only to apples in value as a fresh-market commodity. California is the national leader in terms of strawberry yield per acre and overall production.

California's 10-12 month growing season contributes to the highest strawberry yields per acre in the nation. Rich sandy soil and temperate climate extends California's strawberry growing region 500 miles, primarily in coastal regions from San Diego to Monterey Bay. Some commercial strawberry growing also occurs inland in the San Joaquin (400 acres) and Coachella Valleys (350 acres). California produces strawberry fruit year round, with early production overlapping the Florida crop and late production overlapping the Oregon, Washington and Florida crops; timing is therefore critical to producing the highest profit crop.

In California, perennial strawberries are generally managed as an annual crop and are removed one year after planting, although 6 – 7% of the acreage is keep for a second year of harvesting. Most fields are annually replanted from nursery stock to maximize crop vigor, avoid pest build-up in the soil, and maintain fruit quality throughout the harvest period.

Production Summary

- California produces over 80% of the U.S. fresh market and processed strawberries on 50% of the country's strawberry acreage.
- California's strawberry productivity is over four times higher than most other states': California produces an average of 49,000 lbs/acre, compared to an average of 11,600 lbs/acre for some other states, and a national average of 29,700 lbs/acre; California's productivity is twice that of Florida, the state with the second largest production, and ten times greater than New York's.
- There are about 2,000 acres of strawberry nursery production in California. Use of clean planting stock is critical to producing vigorous, high quality strawberry plants. California nurseries supply almost 100% of the strawberry root stock used within California and a significant portion of the stock used as the foundation for strawberries in other states and countries.
- California produces approximately 20% of the world supply of strawberries and exports about 12% of the California strawberry crop, mostly to Canada, Japan, the U.K., Hong Kong, and Mexico.
- The cost to produce strawberries ranges from $20,000 to $25,000 per acre; the value of the harvested crop from 1992 to 2001 ranged from $18,300 to $31,800 per acre.
- The fresh market takes about three-fourths of the California crop annually, while one-fourth goes for processing.
- Strawberries are a very complex crop to produce in terms of horticultural practices, sensitivity to climatic conditions, soil type, irrigation requirements, fertilizer management, and pest pressure.
- Methyl bromide's planned phase-out by 2005 presents the California strawberry industry with serious challenges and the potential for significant economic loss. This important and widely used pest management tool has been crucial to strawberry nursery plant production as well as commercial fruit production.
- The California strawberry industry has been working diligently in recent years to find effective and economical alternatives to methyl bromide.
- Less than 2% of strawberry acreage in California is managed using organically accepted methods.

The 2002 California strawberry production exceeded 767,000 tons, on over 27,000 harvested acres. The 2003 acreage increased in all the major production districts, for a total of 28,230 acres.

Of the approximately 700,000 tons of California strawberries produced each year, about 75% is harvested for the fresh market, while 25% is frozen for the processed market. Fresh strawberries are rushed from the fields to coolers, where huge fans pull out the field heat, and are then shipped within 24 hours via refrigerated trucks or air freight to their final destination. Strawberries selected for processing are washed, sorted, and chilled quickly to retain flavor and appearance, then sliced, pureed, or kept whole for freezing.

Approximately 12% of the California strawberry crop is exported annually, with Canada, Mexico, the United Kingdom, Hong Kong, and Japan the largest importers. Canada receives the majority of California's exported fresh strawberries, and Japan the majority of its exported frozen strawberries. Future international competition will be mainly from Mexico and China. Mexico is close to the U.S. and it will be able to continue using methyl bromide after California discontinues its use. China's strawberry acreage is increasing and has begun to impact the processed strawberry freezer market. Spain and Italy also are large producers of strawberries, but most of their production remains in the EU.

Use of Certified Nursery Stock

Healthy planting stock is vital to producing high quality strawberries, but producing strawberry nursery plants is entirely different from producing strawberries; therefore a separate pest management strategic plan (PMSP) will be developed for the strawberry nursery industry in California.

The perennial strawberry plant reproduces sexually from seed, and vegetatively by sending out stolons (called "runners") along which new plantlets grow. Reproduction from seed is used only when breeding new varieties; vegetative reproduction is used for propagation of plants used in commercial berry production.

Certified planting stock is developed through a program administered by the California Department of Food and Agriculture (CDFA). The University of California Strawberry Clean Stock Program provides virus tested plants for use in nursery propagation. These "mother" plants maintain the virus-free stock that is the basis for all subsequent variety development and plant propagation.

Nurseries must lead the industry by three to four years to develop planting stock and provide sufficient quantifies of certified stock for use in commercial operations. In all phases of certified plant production, soil fumigation is supervised by local county agricultural commissioners; fields are inspected at planting, during the season, at harvest, and during trimming and packing. Strawberry nursery stock is constantly evaluated in the field to ensure that only healthy, pest-free plants are advanced to the next step in the propagation process. Inspectors look for diseases, insects, weeds, nematodes, and off-type plants.

Stages in nursery plant development include the following:

1. Meristem Plants - Virus-free meristem plants provided by the University of California and some nurseries
2. First Generation Plants - Produced in the screen house to provide protection from virus vectors
3. Foundation Plants (White Tag) - Used by breeders and nurseries
4. Registered Plants (Purple Tag) - Used to increase transplanting stock
5. Certified Plants (Blue Tag) - Sold to growers for use in commercial plantings

Developmental Time for Strawberry Plants and Berries in California

The following table shows the approximate number of days required for a strawberry crop in various developmental stages.

Root and Vegetative Development	Flowering	Fruit Development	Harvest Period
15-30 days after transplanting	Begins 30-60 days after transplanting	22-25 days from flower to fruit	Lasts 3 – 7 months depending on variety and location

California Strawberry Production Regions

Figure 1 illustrates the primary strawberry production regions in California. Strawberry production starts in the southern part of the state and works its way up the coast. Year round production in California has been achieved several times in the last decade and is becoming more frequent.

Figure 1: Strawberry Production Regions

California's Strawberry Industry

The state's strawberry growers report data from the five principal growing areas indicated on the map. Fifteen counties reported a harvest value of over $800 million in 2002.

The University of California has defined the state's strawberry growing regions as follows:

- **Central Coast**: Watsonville, Salinas, Gilroy, Aromas, and adjacent areas
- **Santa Maria**: Two-thirds of the total strawberry production acreage is located in the Central Coast and Santa Maria Valley. These regions encompass the coastal areas of Santa Cruz, Santa Clara, Monterey, San Luis Obispo, and northern Santa Barbara counties.
- **Oxnard Plain**: Coastal Santa Barbara, Oxnard, and Ventura counties
- **South Coast**: One-third of the acreage is planted in southern coastal areas, including the Oxnard Plain and South Coast production areas. The primary counties involved are Ventura, Orange, Los Angeles, San Diego, and western Riverside.
- **Interior Valleys**: About 3% of production comes from interior valleys such as the central San Joaquin (e.g., Fresno and Merced counties) and Coachella Valleys.

The Watsonville and Salinas areas account for about 50% of the state's harvested strawberry value, while the Ventura and Oxnard areas in Ventura County account for over 27%.

Characteristics of the Major Strawberry Production Areas in California*

Characteristic	Central Coast	Santa Maria	Oxnard Plain	South Coast
Transplanting	Oct-Nov	Oct-Nov	Mid-July - Oct	Sept-Oct
Harvest Period	March-Nov	Feb-Nov	Oct - Dec Dec - Jul	Dec-Apr
Main Varieties	Diamante San Juan Aromas Wel Pict S86	Camarosa Diamante Wel Pict	Driscoll proprietary Wel Pict proprietary Camarosa Ventana	Camarosa Ventana
Key Insects	mites lygus whiteflies	mites lygus worms	mites, whiteflies, worms	mites whiteflies
Key Diseases	*Botrytis* powdery mildew anthracnose	*Botrytis* powdery mildew anthracnose	powdery mildew *Botrytis* anthracnose	powdery mildew *Botrytis*
Key Nematodes	root knot foliar	root knot foliar	root knot foliar	root knot foliar

* Based on average years, typical conditions, etc.

Strawberries are grown in a wide range of soil types, from sand to clay loams, depending on what fields growers use in a specific year. Strawberries do best in areas with daytime temperatures in the 70s and nighttime temperatures in the 50s. In most fields, transplants are irrigated by overhead sprinklers followed by drip irrigation under plastic mulch.

Strawberry Varieties in California

Variety selection depends on the growing region and the shipper. New strawberry varieties emphasize yield and quality, harvest efficiency, earliness for Southern California, fruit size, fruit appearance, color, flavor, shipping quality, and resistance to and tolerance of important pests and diseases. Listed below are the most widely produced varieties from California in recent years.

Major Strawberry Pests in California

Insects and diseases of most concern to California strawberry growers are listed below.

Two-spotted Spider Mite (*Tetranychus urticae)*	Serious pest in all California growing areas
Lygus Bugs (*Lygus Hesperus)*	Serious pest in Interior Valleys, Central Coast, and Santa Maria Valley areas, where strawberries are typically grown past May and through the summer
Greenhouse Whitefly *(Trialeurodes vaporariorum)*	Serious pest in Oxnard Plain, South Coast, and parts of Central Coast; has the potential to transmit viruses
Cyclamen Mite *(Steneotarsonemus pallidus)*	Important pest of Central Coast; becoming less significant problem with shift to annual plantings
Strawberry Aphid *(Chaetosiphon fragaefolii)* **Melon Aphid** (*Aphis gossypi)* **Green Peach Aphid** *(Myzus persicae)* **Potato Aphid** *(Acrosiphum euphorbiae)*	Aphids damage fruit in all growing regions, and occasionally cause yield losses because their honeydew deposits on fruit cause sooty molds, and skins shed by aphid nymphs stick to fruit; aphids also transmit viruses that can cause significant economic losses. Aphid control is crucial in nurseries.
Western Flower Thrips (*Frankliniella occidentalis)*	Damage from thrips has increased in recent years, causing bronzing, an important quality concern
Black Cutworm (*Agrotis ipsilon)* **Roughskinned Cutworm** (*Athetis mindara)*	Occasionally seriously damages plant crowns; also can feed on fruit
Beet Armyworm (*Spodoptera exigua)*	Greatest damage occurs to summer- and fall-planted strawberries in the southern growing areas: crown and fruit damage
Corn Earworm, aka **Tomato Fruitworm; Cotton Bollworm** *(Heliothis zea & Helicoverpa Zea)*	Corn earworms are a significant problem only in the South Coastal Region: most damage occurs when the strawberry field is in close proximity to corn or tomato fields.
Garden Tortrix (*Ptycholoma [Clepsis] peritana)*	Contamination of South Coast fields just before the fruit is sent to the processors during late June and July can be a serious problem.
Vinegar Fly aka **Fruit Fly** *(Drosophila melanogaster)* et al.	Primarily a problem in strawberries picked for processing, usually from the Oxnard Plain south
***Botrytis* Fruit Rot** (*Botrytis cinerea)*	Most common and most serious disease of strawberry. Cuts harvest value 30% to 40% in areas where chemical methods are not practiced; loss can reach 50% to 60% under conditions of severe disease; when infestation in the field reaches this level, the economic loss is 100%
***Verticillium* Wilt** (*Verticillium dahliae)*	Increasingly important. Slow growing, but once established extremely difficult to eradicate. Disease spreads from contaminated planting; control at nursery stage is crucial
Anthracnose Fruit and Root Rot *(Colletotrichum acutatum)*	Increasingly important disease of fruit and roots. Appears to come on infected transplants from nurseries and can lead to plant establishment problems in the early season and fruit rot during rainy/foggy weather
***Rhizopus* Fruit Rot** (*Rhizopus* spp.)	After high temperatures can be quite destructive; has caused 20% to 35% loss in production in the Oxnard Plain
Angular Leaf Spot (*Xanthomonas fragariae)*	Impacts increasing; a severe problem in all nursery locations and becoming a greater problem in the Central Coast and South Coast regions
Foliar Nematode (*Aphelenchoides fragariae)* **Root Knot Nematode** (*Meloidogyne hapla)*	Control based on utilizing certified pest- and disease-free nursery stock growing in soil treated with methyl bromide/chloropicrin; nematodes may become a problem with the loss of methyl bromide.

Pesticide Use in California Strawberries

Because strawberries are subject to damage by a very wide range of pests, the acres managed under organic production have remained a very small component of overall production (1-2% of California acreage). Non-organic strawberry production and IPM have relied on several pesticides, especially pre-plant soil fumigants (mostly methyl bromide, and also chloropicrin, 1,3-D, and metam-sodium) as the foundation for establishing a clean crop in the field. Therefore, changes in the availability of methyl bromide have serious implications for the California strawberry industry which must be addressed.

Fumigants have been used to manage several insect, mite, disease, weed, and nematode pests of strawberries. These products are applied at high rates because they are used to treat a volume of space rather than a surface area such as the leaves and stems of plants. Thus, the number of pounds applied is large even though the number of applications or number of acres treated may be relatively small. Fumigants have accounted for about 89% of all pesticide active ingredients by pounds applied in California strawberries. Methyl bromide use decreased by 457,355 pounds from 2000 to 2001 (from 4.2 million to 3.8 million pounds, an 11% decrease). This decrease in methyl bromide use is likely due to an increase in its cost and to the expanded restrictions that CDPR placed on field applications. Methyl bromide was replaced by other fumigants (chloropicrin, 1,3-D, and metam-sodium) whose use increased by 806,000 pounds.

With the loss of methyl bromide, growers are becoming more concerned about weeds, slower growth response of the plant, and root nibblers (pathogens that don't necessarily kill the plant but prevent it from taking off quickly).

All applications of pesticides in California are under the control of the growers, their Pest Control Advisors (PCAs), and/or their Pest Control Operators (PCOs). Growers, PCAs, and PCOs work closely together to insure that only registered pesticide products are used and that they are applied in compliance with all state and federal laws, rules, and regulations, and all label recommendations.

Growers, PCAs, and PCOs maintain communication during planting and production periods through frequent field visits by grower representatives and/or their PCAs. Before any application, the applicator must inform all parties (e.g., harvesting crews, weeding crews, irrigators, etc.) in close proximity to the area to be treated of the intent to apply pesticides, and must also post fields and file post-application paperwork with the appropriate state and/or federal agency. Furthermore, closed systems are mandatory for the application of Toxicity Category I pesticides in California.

Worker Activities

Strawberry yield and quality depend upon the growers' practices, and most growers retain experts in various areas (irrigation, nutrition, pest control, etc.) to manage their crop to its maximum potential. Specific worker activities involved in managing a strawberry crop include: cultural activities (transplanting, mulching, preparing beds, cultivating, irrigating, pruning, thinning, applying fertilizer, harvesting, and analyzing soil/water/plant tissue for nutrient content), and pest management activities (monitoring fields throughout the entire year; scouting for insect, disease, weed, and nematode pests; fumigating; applying pesticides; hand weeding; and releasing beneficial organisms). Specifics of worker activities and timelines for common production and pest management activities in California strawberries are provided in Appendices 2 through 4.

Organic Production

Producing organic strawberries in California is difficult. Only 383 acres of organic strawberries were projected for the 2002 season. Successful acreage is largely land which has little or no *Verticillium* wilt and other components of the strawberry pest complex. As reported at the MBAO 2001 conference, organic culture produced significantly lower yields than conventional culture. Other studies report that yields achieved in organic culture were, at best, only 28% of the yields achieved with conventional culture using soil fumigation. In addition, weed growth resulted in very high hand-weeding costs.

While research continues on organic cultural techniques, root diseases take the heaviest toll on organic strawberries. Before the advent of soil fumigation in the late 1950s, even with the continually improving University cultivars, average strawberry yields were approximately 5,000 lbs/acre. Today, the average yield is almost 50,000 lbs/acre, achieved with soil fumigation with methyl bromide. This striking comparison shows why organic culture would never be able to replace conventional strawberry production in California.

2. PEST MANAGEMENT FOR COMMERCIAL STRAWBERRY PLANTINGS

This section tracks the progression of strawberry production under California growing practices. It provides information on typical field activities and important pests which occur during the following distinctive strawberry horticultural and pest management intervals:

- Land Preparation through Planting
- Vegetative Growth
- Fruit Development through Harvest
- Post-harvest

Calendars for crop development and pest presence in major production regions of California strawberries are provided in Appendices 2 and 3.

The critical research, regulatory, and educational issues of the California strawberry industry are summarized at the end of this document. The work group also included in this PMSP information on the critical use exemption (CUE) for methyl bromide, international registration issues, worker protection issues, and food safety concerns.

LAND PREPARATON THROUGH PLANTING

The following list indicates the general order of the various activities that must be completed prior to fumigating the soil.

Activities Prior to Fumigation

1. Turning in cover crop
2. Soil testing for nematodes and nutrients
3. Soil testing for *Verticillium*
4. Soil preparation (disking, leveling, etc.)
5. Soil amendments and fertilizers applied
6. Irrigation – including laying drip lines
7. Irrigation to get soil moisture correct
8. Water quality analysis
9. Pre-irrigations to bring up weeds prior to planting
10. Herbicide applications
11. Weed clean-up around the fields
12. Preparing regulatory paperwork for use of methyl bromide and/or other fumigants

Soil Fumigation

Highly effective pre-plant soil fumigations are used to control most soil-borne insects, pathogens, and weeds found in strawberries. Materials used include methyl bromide (on >99% of all fields), chloropicrin, metam sodium, and 1,3-dichloropropene. In recent years, township caps on I,3-dichloropropene and other regulatory restrictions have limited the use of many of these materials near public buildings, such as schools. Buffer zones, as established by state and county regulations, often make fumigations impractical or leave too large an area within the field unprotected from pests.

Fumigations are described as either “flat fume” or “bed fume,” meaning that either the whole field or just the beds, respectively, are fumigated. Ninety percent of growers prefer to use the flat fume method, as this manages *Verticillium* wilt more effectively.

The following pests are effectively controlled with fumigation applications:

Insects	Pathogens	Nematodes	Weeds
Root weevils	*Verticillium dahelie*	Root knot	All, except certain perennials and broadleaves; does not control malva, clovers, filaree, oxalis, or bindweed
Cutworms	*Phytophthora* species	Foliar	
Strawberry rootworm	*Colletotrichum* acutatum		
White grubs	Pythium species		
Garden symphylan	Rhizoctonia		
Ground mealybug	Common leaf spot		

For many years, methyl bromide alternatives research for the strawberry industry has been actively on-going, involving USDA-ARS, the University of California, IR-4, the California Strawberry Commission, individual growers, and others. A significant research budget has been allocated for this research since 1992.

Alternative products and techniques are constantly under review, including use of steam, flooding, corn gluten meal, solarization (on the coast), pepper oil, ozone, and others. Cultural techniques such as crop rotation, water management, and new cultivars have been evaluated. However, no one technique appears to provide all of the benefits of fumigations using methyl bromide, and few appear to be drop-in replacement methodologies which will be accepted by the grower community. This area of research will obviously, therefore, continue into the future.

A relatively new technology, “virtually impermeable film” (VIF) makes use of special plastics to almost entirely halt the escape of methyl bromide into the atmosphere. The use of colored, like VIF, plastic has shown some benefits, but causes possible yield reductions. Bio-fumigation, or use of rotational crops such as broccoli or mustards to reduce soil pests, is under evaluation, but it is not nearly as effective as methyl bromide; therefore, commercial prospects for widespread adoption of this technique are limited.

The one product which appears to have a pest control spectrum similar to that of methyl bromide, without the related ozone-depleting characteristics, is iodomethane (to be registered as Midas® by Arvesta Corporation). This product has been in regulatory review for several years by US EPA; if deemed registerable, it will have to undergo evaluation by CDPR. In the bestcase, iodomethane would be registered in 2005.

Other unregistered alternatives to methyl bromide include basamid, propargyl bromide, and sodium azide. However, none of these products appear to be good methyl bromide replacements because they have metabolite issues, are difficult or unsafe to work with, or lack the spectrum of pest control afforded by methyl bromide.

There are alternative fumigants, which are either injected into the soil or applied through the drip system. None of these products are as effective as methyl bromide, or their use is complicated by strict geographical limitations due to concerns about human exposure and/or air quality issues. Registered products include chloropicrin, Telone®, Metam®, Inline® (1,3-Dicloropropene 60.8% plus chloropicrin 33.3% - a drip irrigation formulation of Telone® 35), Telone+Pic® (65%/35% respectively), and co-applications of Telone® and chloropicrin (various rates of each active ingredient injected at the same time in the field, and applied under a tarp).

Planting

Commercial strawberry fields are intensively managed for predictable production at specific times of the year in order to meet market demands. Strawberry transplants are held dormant in cold storage until the appropriate planting time, in the fall or the spring, depending on the particular location and variety. Plant chilling influences plant vigor; more chilling produces more vigorous plants, but over-chilling causes excessive vegetative growth with reduced fruit yield. Optimal chilling also can reduce the impact of spider mite feeding.

Transplants are planted by hand. It takes 20 to 90 days for root and plant development to occur, and then flowering commences. Pollination is accomplished via wind, gravity, or insects; no pollinators need to be provided. Harvestable fruit takes about 25 – 30 days to develop from a pollinated flower. Fields can be harvested for three to eight months depending on the variety and location of the planting.

Work Group Recommendations for Pest Management during Land Preparation through Planting

RESEARCH	• Identify alternative fumigants that can be used in the buffer zones • Evaluate the use of "Virtually Impermeable Films" (VIF) to reduce volatilization of methyl bromide and other fumigants • Continue research on alternative fumigants • Develop new varieties which are resistant to insects and pathogens • Conduct long-term studies on various cultural practices as alternatives to fumigation • Study emission reduction
REGULATORY	• Obtain a critical use exemption (CUE) for methyl bromide until suitable alternatives are registered in California • Retain methyl bromide for nursery production; even organic production requires fumigated nursery stock • Reduce the size of current buffer zone requirements • Re-evaluate fumigant modeling that influences CA regulations • Register iodomethane and other alternatives to methyl bromide • Standardize permit requirements among counties
EDUCATION	• Educate the public about fumigation techniques and benefits • Continue to educate growers about media responses to fumigants • Involve California Agricultural Production Consultants Association **(**CAPCA) and other organizations in educating growers and the public • Continue educational activities with growers and the public about alternatives to methyl bromide and about safe fumigation practices • Continue to educate regulators about strawberry growing practices and pest management issues

DORMANCY
(after Planting up to Root Establishment)

After transplanting, adventitious roots grow from the stem tissue of the plant crown. The root system continues to establish itself during the first two to three months after planting, as soil temperatures rise. Mulch is commonly used to help increase soil temperatures and promote plant growth.

Throughout this period, it is very important that the crown remains in contact with the soil and that the correct amounts of water and nutrients are provided. In addition, salinity of the soil and water must be monitored since high salt levels can retard plant growth.

Mite and white fly control can become important, as relatively low densities of these pests can result in loss of yield and excessive pest populations later in the production season.

Cultural Activities

• Irrigation	• Fertilization
• Water quality analysis	• Herbicide applications
• Insect, mite, and disease monitoring and control	• Weed cleanup around the fields/field sanitation

Work Group Recommendations for Pest Management in California Strawberries during Dormancy

RESEARCH	• Identify alternative fumigants that can be used in the buffer zones • Research effective use of VIF films • Continue research on alternative fumigants • Develop breeding plants that mitigate pests and pathogens • Conduct long-term research on cultural practices as alternatives to fumigation • Research methyl bromide emission reduction
REGULATORY	• Retain methyl bromide for nursery production; even for organic production fumigated nursery stock is necessary • Reduce current buffer zone requirements • Revisit fumigant modeling that drives California regulations • Register iodomethane • Standardize regulatory permit requirements • Obtain methyl bromide CUE for fumigation use after 2005
EDUCATION	• Educate the public about fumigation techniques and benefits • Continue to educate growers regarding media responses to fumigants • Involve CAPCA and other organizations in educating growers and the public • Continue educational activities about alternatives with growers and the public

	• Continue to educate regulators about strawberry growing practices

VEGETATIVE GROWTH

Pest management is extremely important during this phase, when young transplants adapt to their new location, break dormancy, and develop runners and new plants. This period of development lasts 60 to 90 days, depending on the variety, location, and seasonal temperatures.

Cultural and Worker Activities

- Irrigation
- Fertilization
- Water analysis
- Irrigation monitoring
- Pest monitoring
- Visual inspections of plant health/vigor
- Plant removal
- Insecticide, miticide, and fungicide applications
- Dust control (water/oil roads)
- Petiole or plant tissue analysis
- Replanting
- Removing runners
- De-blossoming
- Hand weeding
- Releasing beneficial insects
- Sanitation
- Plant and establish trap crops
- Vacuum fields to remove insects (organic growers)

INSECTS AND MITES

Insect and mite pressure varies according to location and season. While the single most serious pest of strawberries is the two-spotted spider mite, worms, aphids, and whiteflies can also cause concern during this stage of strawberry development. Some general predators, such as big-eyed bugs, minute pirate bugs, damsel bugs, spiders, and ladybird beetles, provide limited biological control of these pests.

The two-spotted spider mite, a key pest of strawberries in all California growing areas, expresses its damage as stippling, scarring, and bronzing of the leaves and calyx. This damage can be minimized by using cultural practices that promote vigorous plants, but strawberry cultivars vary in susceptibility to two-spotted spider mite infestation and tolerance of the mite feeding. Mite populations must be carefully monitored throughout the season and products should be rotated in order to manage the development of resistance. Crop-free periods may reduce the rate at which spider mite populations become resistant to miticides. Controlling road dust is important in inhibiting mite infestations because dusty conditions favor the build-up and dispersal of two-spotted spider mites. Releases of predatory mites can reduce two-spotted mite populations, especially early in the season when miticides are not being used. However, biological control alone rarely provides control of spider mites sufficient to prevent yield loss.

While the cyclamen mite is an important pest of central coast strawberries, it has become a less significant problem as fewer strawberry fields are retained for multiple-season use due to the shift to annual plantings. Cultural controls of this pest include preventing movement of this species by pickers, bees, birds, and equipment, including strawberry freezer trays. When using chemical controls for cyclamen mites, a high rate of water per acre is necessary to soak the unfolded leaves and immature flower buds located in the crowns. Crop rotation, dust reduction, and biological control provide limited management of this pest. Six-spotted thrips, an important natural enemy, feed on cyclamen mites when they become prevalent.

Releases of predator mites, minute pirate bugs, lady beetles, six-spotted thrips, and a cecidomyiid fly maggot (*Feltiella spp.)* have all been used as biological controls in strawberries. Of these, only predator mite releases are commonly employed. Predator mites are most effective when used in controlling light infestations of mites. These

biological control methods for mites are typically used in conjunction with chemical pest management techniques because these combinations are much more effective than biological control alone.

Chemicals are extremely important pest management tools for strawberry growers, but two-spotted spider mites in particular have rapidly developed resistance to miticides. Alternating use of miticides with different modes of action helps to reduce the development of resistance to a specific miticide. However, organophosphate, carbamate, and pyrethroid insecticide applications can stimulate two-spotted spider mite outbreaks by disrupting the balance with beneficial arthropods.

Agri-mek® is a fairly effective miticide, but there are resistance concerns with this product. Savey®, an ovicide, provides very good control of eggs, and is a good tool for IPM programs; however, timings of applications are very important for maximum mite control, and there are field reports of resistance developing.

Acramite® is also a good material for use in IPM, but application timing is critical. Brigade® and Danitol® provide good mite control, but both are harsh on beneficials and should not be applied to control spider mites. Vendex® provides only poor to fair control of mites, and Kelthane® is only moderately effective and has resistance issues. Omni Supreme® oil can be used during cool weather before flowering, but caution is necessary to avoid phytotoxicity.

Black cutworms, rough-skinned cutworms, and beet armyworns can be important lepidopterous pests of strawberries. Weed control is paramount to preventing a serious cutworm problem; weedy fields tend to attract more moths to lay their eggs. Early-season damage by newly hatched cutworms generally appears as small, web-less perforations in the newly expanding crown leaves. As soon as substantial leaf and/or stem cutting is noted, baits are applied; bait applications are also made immediately after weeding, to prevent migration to crop plants.

The greatest damage from beet armyworm occurs to summer and fall-planted strawberries in the southern growing regions of the state. Newly hatched beet armyworms are foliage feeders, skeletonizing the upper or lower leaf surfaces adjacent to their egg mass. Young larvae feed on foliage before attacking fruit. Larger larvae can attack the crowns of young plants and kill them. Weed control in and near the field minimizes armyworm populations because the adult moths are attracted to weeds for egg laying. Biological control is provided by the ichneumonid parasite, *Hyposoter exiguae,* and armyworms often become diseased with a virus that can cause high mortality.

Bt can provide fairly good control of lepidopterous pests, but early and multiple applications are usually required to maintain acceptable control levels, and resistance may be occurring. Lorsban® provides fair to good control of worm pests in strawberries, and has only a moderate effect on beneficial insect and mite species. Lannate® provides excellent control of cutworns and beet armyworms, and Brigade® and Danitol® also provide good worm control, but these three products are harsh on beneficials. Sevin® is not effective for armyworms; there is a reentry interval (REI) issue related to the use of the bait formulation, and Sevin® spray is harsh on beneficials and bees. Success® and Entrust® are ineffective on cutworms, but work well on beet armyworms and are soft on beneficials.

Aphids occasionally cause yield losses in California strawberries because of their honeydew production. They also transmit several viruses that can cause significant economic losses if fruit plantings are maintained for more than one year (which is rare). Cultural controls for aphids include row covers and dust reduction in and around fields.

Biological and natural control of aphids is accomplished using parasitic wasps, lacewings (especially nymphs), big-eyed bugs, minute pirate bugs, damsel bugs, and ladybugs; ladybugs are often released into fields to control aphids. In some circumstances biological control is sufficiently effective to provide an economically viable alternative. Thus, growers should monitor aphid populations and avoid applications of insecticides/miticides that will destroy natural enemies. Removing weeds in strawberry and nearby fields that harbor aphids also will help to manage populations.

When aphid pest pressure reaches a trigger level (sometimes when 30% of young tri-foliate leaves are infested), chemical treatments are made. Diazinon, malathion, and Lorsban®, all organophosphate insecticides, provide only fair control of aphids. These products are harsh on beneficials, and use of Lorsban® is limited near schools. Summer oils work fairly well, but can cause phytotoxicity to plants and are disruptive to beneficials. Azadirachtin works only fairly well, requires multiple applications, and is very expensive.

Whiteflies are always present in strawberry fields (their occurrence has become more widespread in the past few years for unknown reasons). Whiteflies suck plant juices and, at high population levels, can excrete large

amounts of honeydew on which a sooty mold fungus grows. Occasionally populations build up to damaging numbers causing economic loss. There are geographic differences in the importance of this pest.

An area-wide approach to whitefly management is essential for control because of the broad host range and overlapping of crop host cycles. This approach involves breaking the continuous generation cycles of this pest by cultural or chemical means. For example, multiple-year plantings should be avoided in areas where whiteflies are especially problematic, and hosts which are no longer being harvested should be destroyed before new strawberry plantings are established. Trap crops have proven only marginally effective and can even serve as bridge hosts; the use of sticky tapes as a control measure is not very effective. Released parasitic wasps are costly and few survive in strawberry fields.

Admire®, under a Section 18 only until December 23, 2003, provides moderately good control of whiteflies. However, only one application is allowed under this label. Esteem®, also available under a Section 18, currently has a two-day PHI. Lannate® provides fair control of adult whiteflies, but coverage is an issue since this is a contact insecticide. Danitol® in combination with Malathion provides only fair control of adult whiteflies, and only a limited number of applications may be made; also, these materials are harsh on beneficials. Malathion, Danitol®, Brigade®, and oil by themselves are not effective against whiteflies. Azadirachtin provides only poor control of whiteflies.

Work Group Recommendations for Insect and Mite Management in California Strawberries during Vegetative Growth

RESEARCH	• Research alternates to fumigant controls of soil insects • Research whitefly control options • Develop a resistance management strategy for spider mites • Research additional biological controls, including rearing, efficacy, and survivability • Research impacts of new material on beneficials and IPM programs
REGULATORY	• Register Knack®, Actara®, Platium®, Applaud®, and Fulfill® for whitefly control • Register Zeal® and Kanemite® for spider mite control • Get full registration for Admire® • Shorten REI for carbaryl bait • Change Lorsban® label to eliminate bloom restriction
EDUCATION	• Provide resistance management training for PCAs and growers • Develop educational materials targeted to minority growers (non-English, etc.)

WEEDS

Weed control in strawberries has traditionally been based on using certified pest- and disease-free nursery stock growing in soil treated with methyl bromide/chloropicrin; this treatment has limited herbicide usage (compared to use in other commodities). Thus, the potential loss of methyl bromide is of great significance to future weed management in California. In addition, the regulations on buffer zones for methyl bromide and other fumigants require that new weed control techniques be evaluated and adopted.

California's longer growing season produces a greater weed control challenge. Strawberries are highly susceptible to weed competition immediately after transplanting, when the plants are small and frequent sprinkling provides ideal conditions for weed germination. Most weeds that invade strawberries are annuals. During stand

establishment, little mallow, California burr clover, sweet clover, and filaree are common because their seeds survive fumigation. Once strawberries are in the bearing stage of growth, wind-blown seeds, including those of sowthistle, common groundsel, purple cudweed, and grasses, may become problems.

Annuals:		**Perennials:**
• Annual bluegrass	• Filaree	• Bermudagrass
• Spotted spurge	• Little mallow (cheeseweed)	• Field bindweed
• Sweet clover	• Sowthistle	• Yellow nutsedge
• Cudweed	• Common groundsel	
• Knotweed	• California burr colover	

Effective weed management in strawberries requires a combination of cultural practices, pre-plant soil fumigation, and additional herbicide applications when necessary. Proper pre-plant field preparation and bed preparation are essential for a good weed control program throughout the year. While traditionally broadcast (flat) fumigation has provided good control of weed populations across the entire field, the increasing use of bed fumigation (i.e., only the bed is fumigated) leaves row middles untreated, allowing weed populations to build up. Weeds that have escaped fumigation treatments may be controlled using directed sprays of contact and systemic herbicides. Devrinol® is used on furrow bottoms with fair to good results for control of annual weeds just after transplanting. However, it is not registered for pre-transplant applications. Also, its use is not feasible in Southern California where whole-season plastic mulches are used, because this might lead to phytotoxicity problems. Gramoxone® is a good contact herbicide when used as a directed spray. Poast® and Prism® are good grass herbicides. Prism® has the added benefit of controlling annual bluegrass, but it must be used prior to bloom. Neither of these products controls nutsedge. Goal 2XL® is registered for use on strawberry fallow beds 30 days prior to transplanting.

Increasing buffer zone requirements leave sensitive areas treated with only low doses of fumigants or no fumigant at all. Weed control in these buffer areas must be addressed, and increased use of herbicides is the most logical control measure.

Non-chemical weed controls include sanitation of fields and equipment, cultivation, hand weeding, crop rotation, soil solarization, flaming, and use of organic or synthetic (dark colored plastic) mulches. No biological control agents are available for weeds.

Work Group Recommendations for Weed Management in California Strawberries during Vegetative Growth

RESEARCH	• Evaluate pre-plant herbicides which can be put under plastic, under Southern California conditions • Evaluate light-penetration and soil-warming characteristics of plastic mulches • Evaluate cultural and chemical techniques for control of nutsedge • Develop weed management options and techniques for use in organic systems
REGULATORY	• Work with registrant and CDPR to allow registrations of sulfentrazone (Authority®) in California • Re-register Roundup® as a directed spray for weed control in furrows
EDUCATION	• Provide training to growers and PCAs on nutsedge management

DISEASES

Disease management begins before field preparation. Proper site selection, fumigation, drainage, and use of resistant cultivars and certified and vigorous planting stock will help to establish a healthy stand.

Root and crown diseases are caused by pathogens present in the soil or water and/or organisms present on infected transplants. Soil fumigation and use of certified transplants are the major ways to avoid disease problems.

Phytophthora is a genus of soil-borne fungi; plant stunting and wilting are common symptoms. *Phytophthora* species also attack root tissue, causing a brown to black root rot. Cultural control of the fungus includes locating strawberry fields on well-drained soil, using raised beds to provide optimum drainage, and using less susceptible cultivars. Using drip irrigation and managing irrigation schedules to minimize soil saturation near plant crowns are key methods to reduce losses from this pathogen. Aliette® and Ridomil® Gold also provide good control of these diseases, although there is resistance to these materials.

Colletotrichum acutatum can cause two potentially serious diseases of strawberry, anthracnose fruit and root rot. Severe root infections can cause plant establishment problems in the fall and reduce yields. Washing roots with running water prior to planting can remove conidia and appressoria of the pathogen. Dipping plants in Quadris® may reduce the severity of the disease. Quadris®, Cabrio®, Switch®, and Captan® provide fair to good control, although resistance seems to be developing to the strobilurins (Quadris® and Cabrio®). In severe cases, replanting with clean stock may be necessary.

Verticillium wilt is slow-growing, but once established, is extremely difficult to eradicate. Spread of the disease from contaminated planting stock is an increasing concern, making control of this disease at the nursery stage crucial. Cultural controls include using resistant varieties, limiting over-fertilization, rotating crops, and controlling irrigation to limit over-watering. In combination with these tactics, chemical fumigants help to reduce losses from *Verticillium* wilt. There are no fungicides that control this disease.

Cultural controls for black root rot (*Pythium*, *Rhizoctonia*, and *Cylindrocarpom*) include crop rotation and water management. The fungicides Aliette® and Ridomil® Gold provide good control of these diseases, but there is resistance to these materials.

Most foliar diseases of strawberries are spread by rain or splashing water, but some are brought to the field on infected transplants. Monitoring fields for signs and symptoms of diseases is critical throughout the growing season. Clean nursery stock is essential for minimizing all diseases. Fungicide applications should be made as needed.

Powdery mildew, a significant disease in the coastal growing regions, is most serious in areas of high humidity. The disease is a problem on all plant parts from transplant through bloom, reducing yield and quality. Powdery mildew is controlled mainly by applying fungicides as soon as the disease is detected; thus, monitoring is extremely important in reducing disease incidence. All fungicides are applied about one month after planting and again three to four weeks later.

A biological control agent for powdery mildew is commercially available: *Ampelomyces quisqualis* (AQ10), a bio-fungicide which is a selective fungal hyper-parasite, works well early in the season, but is less effective in inland growing regions. It works well only under low to moderate disease pressures, and normally requires multiple applications. Other non-fungicidal materials such as potash soap and chitosan (Elexa®) are available, but have only limited efficacy. Fixed copper is not effective for powdery mildew control.

Two formulations of sulfur provide good control of powdery mildew, but micronized and dusting sulfur can cause phytotoxicity problems if temperatures are over 85-90 degrees. Abound®, applied early, provides good disease control, but is very expensive and may stunt plants. Captan provides only poor to fair control of powdery mildew. Rally® works fairly well on powdery mildew, although there is resistance in the field. Potassium bicarbonate works well, but requires multiple applications, and cannot be mixed with other pesticides or fertilizers. Mono potassium phosphate (MPK) works fairly well as a powdery mildew material. In fields which are thought to have powdery mildew problems, “Bug Vac” devices should not be used to physically remove lygus bugs and other pests, as this technique increases the spread of this disease.

Botrytis fruit rot can be a serious pre-harvest and post-harvest disease. The conidia of this disease are wind and splash dispersed. The pathogen infects flowers during wet or foggy weather, but the disease does not become apparent until the fruit ripens or after harvest in storage. Effective control requires applications of fungicides such as captan, thiram, Switch®, and Elevate® during flowering.

Common leaf spot, the most important strawberry leaf spot disease in California, can, if left unchecked, decimate the productivity of entire fields. Common leaf spot can be a problem in all fruit production areas, but is usually less prevalent in the drier interior valleys and southern growing regions. The use of drip irrigation can limit the onset of the disease; avoid use of overhead sprinklers.

Protective fungicides are effective if applications are made ahead of warm, damp weather. Captan is moderately effective in controlling leaf spot, but it is categorized as a B2 carcinogen, and can be used only in limited amounts per season. Topsin M®, thiram, and Rally® are registered, but provide only poor to fair levels of control.

Viruses (mottle, crinkle, mild yellow edge, vein banding, and necrotic shock) may affect strawberry plants. Most are spread by insects, and usually more than one virus is present in an infected plant. Using clean nursery stock is the primary means of avoiding problems with viruses. Vector control is only minimally effective because the diseases are usually established before control actions are taken. There are no chemical controls.

Phytoplasmas, such as lethal decline and green petal, are transmitted by leafhoppers. As with viruses, using clean transplanting stock is the best way to minimize these disease problems. Leafhopper control is only moderately effective.

Work Group Recommendations for Disease Management in California Strawberries during Vegetative Growth

RESEARCH	• Evaluate new chemical and biological control agents for powdery mildew • Develop information on the epidemiology and control of *Colletotrichum acutatum* • Develop improved methods for the production of pathogen-free transplants • Determine which soil-borne diseases will not be controlled with methyl bromide; evaluate management options • Evaluate nutrient status of plants and soil as these factors relate to disease management
REGULATORY	• Harmonize international tolerances, especially for new U.S. registrations • Register Quintec® and Flint® for control of powdery mildew • Remove plant-back restrictions on Switch® and Procure®
EDUCATION	• Provide training on fungicide resistance management for growers and PCAs • Educate the public on the benefits of fungicides in producing high quality fruit with a long shelf life

NEMATODES

Root knot and foliar nematodes are the most important plant parasitic nematodes detected in soils from California strawberry fields. Plant parasitic nematodes feed on roots, reducing water and nutrient uptake, and, ultimately, vigor and yield of plants. Foliar nematodes cause dwarfing or leaf distortion.

Nematodes are not likely to be pests if the soil has been fumigated and certified planting stock is used. In certain cases, however, nematodes can remain deep in the soil, protected from fumigations by organic matter and other plant debris. Fumigation has generally been an effective means to reduce losses due to nematodes; however, restrictions on the use of several fumigants are forcing growers to evaluate new methods of management.

Non-chemical tactics used for managing nematodes include careful field selection, use of certified nursery stock, hot water treatments, sanitation, crop rotation, and soil solarization.

Work Group Recommendations for Nematode Management in California Strawberries during Vegetative Growth

RESEARCH	• Develop control measures for in-season nematode control • Develop nematode-resistant cultivars

VERTEBRATE PESTS

A number of vertebrate species may move into or live near strawberry fields: squirrels, mice, moles, and gophers are the most common. Searching for water and food, they may damage the crop or the irrigation system. The potential for damage by vertebrates varies from field to field and region to region. Fields located near uncultivated areas are more likely to be invaded or re-invaded by certain vertebrates. Whole plants and large portions of fields may be lost to these pests. Controls include poison baits, noisemakers, repellents, protective netting, trapping, and lethal control. Restrictions on lethal control will vary by county.

There are no current work group recommendations for vertebrate control in early season strawberries.

FRUIT DEVELOPMENT THROUGH HARVEST

Cultural and Worker Activities

• Irrigation • Fertilization • Soil testing for nutrients • Visual inspections of plants • Insecticide, miticide, and fungicide applications	• Irrigation monitoring • Petiole or plant tissue analysis • Harvesting every 3-5 days (PHIs must allow for this activity or the pesticide cannot be used) • Pest monitoring • Hand weeding as needed

It takes 21-25 days for a strawberry flower to mature into a harvestable fruit. Hand-harvesting continues for several months on a three to five day cycle until the field's productivity diminishes significantly. During the lengthy period in which a field is in production, mites, insects, diseases, and birds are continually monitored.

INSECTS AND MITES

The insects and mites that infest strawberry fields during this period are basically the same as those that occur in the vegetative stage. Besides mite and worm pests, whiteflies, aphids, thrips, and lygus bugs must be carefully monitored. Biological and cultural controls are used for some of these pests when effective and practical; however, chemical controls are the primary means to combat pests once fruiting has begun, in order to maintain crop quality. Only products that have acceptable post harvest intervals (PHIs) can be used during this time.

Mite control products during fruit development through harvest are similar to those used for early season mite control. Agri-mek® is a fairly effective miticide, but has potential resistance problems. Savey®, an ovicide, provides very good control of eggs, so it must be used before mite populations become very high; however, there are reports of resistance developing in the field. Acramite® is a good material for use in IPM because of its limited adverse effects on beneficial arthropods. Brigade® and Danitol® provide good mite control, but both are harsh on beneficials, and are not recommended by the University of California for use against spider mites. Vendex® provides only poor to fair control of mites. Kelthane® is only moderately effective and has resistance issues.

Vinegar flies (fruit flies) are more of a problem in very ripe fruit that is allowed to stay on the vine in preparation for processing (freezer and cannery). Flies tend to build up on nearby over-ripe fruit and then lay eggs on ripe fruit in the field. Sanitation to remove very ripe fruit and trash between rows will help to limit sources of this pest. Malathion provides only poor to fair control of vinegar flies; Naled® provides fair control. Pyrethroids targeting adult flies are probably the best choice, but only two products are registered and the number of applications is limited.

A variety of aphid species can transmit viruses to strawberry plants. Honeydew secretions from aphids cause sooty mold to grow on leaf and fruit tissue, rendering the fruit unmarketable. Natural control of aphids by parasitic wasps and several other predator species can occur. In some circumstances, such as with the melon aphid in southern California strawberry-growing regions, the levels of biological control can be economically viable,

Chemical treatments are made when natural controls have not been able to keep up with developing populations. Lorsban® and diazinon work fairly well for aphids; however, the PHIs for these products (21 days and 5 days, respectively) render them impractical to use at this time of year. Also, use of Lorsban® near schools is limited. Lannate® works well as an aphicide, and has PHIs of 10 days for freezer berries and three days for fresh berries. Azadirachtin works only fairly well, requires multiple applications, and is very expensive. Success® is not effective against aphids, and summer oils are phytotoxic during this period.

Lygus bugs are one of the major causes of irregularly-shaped, cat-faced strawberries. Monitoring fields for nymphs and adult lygus bugs is critical to their control. Successful management of lygus bugs includes control of weed hosts during the winter months, and monitoring for the appearance of lygus nymphs on weed hosts. Weed control along roadways, ditches, and field borders helps prevent spring build-up of lygus bugs. Some growers use

trap crops to attract lygus away from strawberry fields, but the flowers must be maintained or the lygus will migrate back to the strawberries.

Big-eyed bug and *Anaphales* parasites are the most important natural enemies of lygus bugs. No natural enemy, however, is entirely successful in keeping lygus from reaching damaging levels when there is a heavy migration of adults into strawberry fields, typically when wild vegetation dries up in the spring.

Lannate®, Danitol®, and Brigade® are the most effective pesticides for control of lygus bugs, if applied when they are most susceptible, in the first and second instar nymph stages. Insecticides applied to later nymphal stages and adults are less effective. Short residue insecticides do not control lygus bugs, often necessitating repeated applications of these materials. Dibrom® provides only poor to fair control and can result in fruit bronzing. Malathion, diazinon, and azadirachtin provide only poor to fair control of lygus.

Lepidopterous pests occasionally can reach damaging numbers; their larvae may feed directly on developing flower clusters or fruit. Bts can provide fairly good control of lepidopterous pests, but usually require early and multiple applications to maintain acceptable levels of control. Lorsban® provides fair to good control, but also moderately affects beneficial insects and mites. Lannate® provides excellent control of cutworms and beet armyworms, but is very harsh on beneficials. Sevin® is not effective for armyworms and has REI problems related to its bait formulation. Success® is not effective on cutworms, but works well on beet armyworm, and is not harsh on beneficials.

Whitefly control tactics used when fruit is developing are virtually the same as those for the vegetative stage. If insecticides are needed, only products with acceptable PHIs can be used. In areas with perennial whitefly problems, Admire® should be applied at planting, and during the fruiting period if populations increase. Lannate® provides fair control of adults, but coverage is an issue since this is a contact insecticide. Esteem® can be used during the season (2-day REI) under a Section 18 exemption and can provide excellent control. Danitol® and Brigade® in combination with malathion provide fair control of whiteflies, but the number of applications which may be made is limited, and both products are harsh on beneficials. Malathion alone is not effective for whiteflies. Azadirachtin provides only poor control of whiteflies.

Damage from Western flower thrips has increased in recent years, impacting both fruit yield and quality; often small fruit will drop from the plants. Thrips may also cause fruit bronzing. Minute pirate bugs provide some level of predation on thrips. Since the thrip also is a predator of mites, a key pest, chemical controls are necessary only when thrip populations become very high. Lannate® and Success® are effective against thrips, but Success® provides shorter residual activity.

Work Group Recommendations for Insect Management in California Strawberries from Fruit Development through Harvest

RESEARCH	• Evaluate chemical and biological controls of lygus • Evaluate cutworm controls • Evaluate whitefly controls for harvest time • Develop a resistance management strategy for spider mites
REGULATORY	• Register whitefly materials for in-season sprays • Harmonize international tolerances or MRLs to insure no trade irritant problems will evolve with fruit destined for export market
EDUCATION	• Educate the public and the regulatory community about the interface between urban and agricultural land

WEEDS

Annuals:	Perennials:
• Little mallow	• Bermuda grass
• Sweet clover	• Field bindweed
• Sunflower	• Yellow nutsedge
• California burr clover	
• Filaree	

Weeds are highly competitive with strawberries, but by the fruit development phase, the canopies of the new runner plants will out-compete many of the weeds. Hand weeding and contact herbicides are used to remove any remaining weeds at this time of the season.

Work Group Recommendations for Weed Management in California Strawberries from Fruit Development through Harvest

Regulatory	• Maximum of 3-day PHI needed for any new herbicide registrations • Register carfentrazone and flumioxazin for directed, in-furrow use for control of weeds
Education	• Inform registrants that the maximum PHI for any new herbicide must be no greater than 3 days

DISEASES

As with foliar diseases, fruit can be infected by soil-borne pathogens and/or through water that carries disease organisms. Diseases that impact the fruit can be the same organisms that were problems earlier in the season.

The single most important disease of the fruit, gray mold (*Botrytis*) is favored by cool, moist conditions. It is managed by using plastic mulch to prevent the fruit from touching the soil surface, using proper irrigation techniques, and timing fungicide applications for optimal efficacy.

Protective treatments of gray mold fungicide are made in season when environmental conditions favor disease development. This helps protect the fruit just prior to harvest and on into storage and transit to the market. Limiting overhead irrigation and keeping canopies open to encourage air flow will also help reduce gray mold problems. Predictive models are used by a few growers, but this tool needs refinement. No biological controls are available for this disease; chemical control is usually needed.

Several fungicides are available, but it is important to rotate them to avoid build-up of resistance. Elevate® provides excellent control of *Botrytis,* with a maximum of four applications allowed per season. Switch® is an excellent fungicide, but has plant-back restrictions of one year for non-labeled crops. This product also is restricted to a limited number of applications based on pounds of active ingredient allowed per year. Captan, thiram, and Topsin M® all provide good control of *Botrytis*, but a closed cab on the tractor/sprayer must be used with captan. Quadris® works fairly well as a *Botrytis* suppressant. Messenger® has not had consistent results and is not certified for organic growers.

Rhizopus rot and *Mucor* fruit rot are spread by wind and insects that move spores from infected leaf trash to fruit; infection occurs only through wounds in ripe fruit. This disease is managed mainly by using plastic mulch to limit fruit contact with infected soil and plant debris. *Rhizopus* rot (but not *Mucor*) can be minimized by providing prompt cooling after picking, and by maintaining proper storage temperatures.

Powdery mildew is limited mostly to the coastal growing regions and northern nurseries; it causes little damage in inland growing regions. The infected flowers produce deformed fruit, or no fruit at all. Severely infected flowers may be completely covered by mycelium and killed. Infected immature fruits become hardened and desiccated, often resulting in fruit "bronzing." Irrigation management aids in controlling this disease, and growers use resistant cultivars where practical. Sulfur provides good control of powdery mildew, acting as a physical barrier to the pathogen. Fungicides are used to protect flowers and fruit. *Ampelomyces quisqualis* (AQ10®), a bio-fungicide which is a selective fungal hyper-parasite, works well against powdery mildew early in the season, but is less effective in inland growing regions.

Resistance management should be practiced with all fungicides. Using proper rates and rotating chemistries will help to avoid development of tolerance of and resistance to these important tools.

Work Group Recommendations for Disease Management in California Strawberries from Fruit Development through Harvest

RESEARCH	• Find fungicide with kickback activity on *Botrytis* fruit rot • Identify new fungicides that improve control of anthracnose fruit rot
REGULATORY	• Register more than one fungicide at a time for resistance management • Ease plant-back restrictions on Switch® • Allow for multiple Section 18s of different chemistries for resistance management
EDUCATION	• Educate growers on the epidemiology and control of *Botrytis* fruit rot and *Colletotrichum* diseases

VERTEBRATE PESTS

Several species of birds (robins, goldfinches, waxwings, starlings, and curlews) and mammals can be serious pests when the fruit starts to ripen. Controls include baits, noisemakers, repellents, protective netting, trapping, and lethal control. Restrictions on lethal control vary by county.

There are no work group recommendations for vertebrate control during this time period.

POST-HARVEST

DISEASES

Post-harvest disease control begins in the field, with vigorous plants and sound fruit that is free of disease organisms. Fruit diseases are caused by pathogens that survive in soil or water; keeping fruit away from the soil and/or away from splashing water will help reduce losses. There are no post-harvest chemical treatments for disease; protective treatments are made in season when environmental conditions favor disease development.

Strawberries are harvested very carefully by hand and are not subjected to washing at time of harvest. Within an hour or two of picking, they are placed in trucks and transported to a cooling facility where they are cooled, typically by forced air at 34° F. Cooling reduces decay and prolongs the shelf-life of the fruit.

Nearly all strawberry fruit is shipped to market in refrigerated trucks, kept at 34-36° F. The typical timeline from harvest to delivery destinations is as follows

TIME	DAY 1: HARVEST	DAYS 2- 6: SHIPPING WITHIN U.S.	RECEIVING DOCK TO U.S. MARKET	DAYS 2- 6: SHIPPING OUTSIDE U.S.
ACTIVITIES	Delivery to yard and cooling (1-4 hours)	To Seattle - 1 day To Denver - 2 days To Chicago - 3 days To NY/Boston - 4 days	1 day	Canada - 3-5 days Mexico - 3-5 days Japan (air freight) - 1 day

Gray mold (*Botrytis*) is the most common and serious post-harvest disease of strawberries due to its ability to grow at the temperatures in which fruit is stored. Infection by this organism, and several other pathogens, usually begins early in the season, but is not expressed until the fruit has been harvested or held in storage. Individual fruits can be lost in the field, but decay after harvest may spread rapidly to other fruit in packages, leading to the entire loss of the stored product destined for the retail market.

Removing over-ripe fruit during harvest and discarding all berries with any sign of decay while packing will help to reduce loss potential. Prompt cooling after picking, and maintenance of proper storage temperatures under controlled atmospheric conditions, will also reduce problems with *Botrytis*.

Rhizopus rot and *Mucor* fruit rot are spread by wind and insects that move spores from infected leaf trash to berries; infection occurs only through wounds in ripe fruit. This disease is managed mainly by using plastic mulch to limit fruit contact with infected soil and plant debris. *Rhizopus* rot (but not *Mucor*) can be minimized by providing prompt cooling after picking and maintaining proper storage temperatures.

Pre-shipment fumigations are required by Japan; in addition, other countries have general fumigation requirements for insects and diseases which must be adhered to or loads will be rejected.

INSECTS

Vinegar fruit flies are considered a pest of processed fruit because they lay eggs in fruit that is allowed to fully ripen in the field before being harvested for the freezer or canning industry. The best treatment for this pest is a pyrethroid insecticide or malathion, applied pre-harvest to prevent maggots in the processed fruit. Good sanitation practices both in the field and around fruit processing areas is important to reduce vinegar fruit fly populations.

Work Group Recommendations for Post-Harvest Insect and Disease Management

Research	• Develop improved methods to package and move fruit to market

STRAWBERRY INDUSTRY CONCERNS

IR-4 SYSTEM PROJECT PRIORITIES

The IR-4 research and registration process will become increasingly important as new products are required to replace pest controls, particularly weed control, formerly provided by methyl bromide. New active ingredients with unique modes of action to manage resistance are always needed for spider mite control. Lygus bugs, flower thrips, *Phytophthora*, *Colletotrichum*, and other pests are in need of management tools also.

The Strawberry Work Group will coordinate with the Western Region IR-4 office to submit pesticide clearance request (PCR) forms for product needs identified in this strategic plan.

CRITICAL USE EXEMPTION (CUE) FOR METHYL BROMIDE

Methyl bromide production is scheduled for phase-out by 2005. Research continues on alternatives such as Telone®, methyl iodide, propargyl bromide, and methyl isocyanate; however, it appears that both risks and regulations will limit these products' uses or delay their registrations. Several alternatives are currently being evaluated in field trials, but no single product or technique will completely replace this efficacious tool. Meanwhile prices for methyl bromide will continue to rise and availability may be hampered as markets for manufacturers are removed by regulatory action.

The replacement of methyl bromide remains a serious concern for both the strawberry nursery industry and commercial fruit producers. The California Strawberry Commission and the California Strawberry Nursery Association completed CUE applications for their respective industries. Applications for the 2005 and 2006 CUE were submitted in early September 2002 and August 2003, respectively. CUEs approved through US EPA will be forwarded to the Methyl Bromide Technical Options Committee (MBTOC), the international authority charged with granting approvals for exemptions from the Montreal Protocol.

Work Group Recommendations for CUEs

REGULATORY	• It is imperative that a critical use exemption (CUE) for methyl bromide be obtained for the California strawberry industry until suitable replacement products are evaluated and registered in California

INTERNATIONAL TRADE/CODEX

Trade must not be hampered by regulatory differences between exporting and importing countries. As new products are registered in the United States due to FQPA and the phase-out of methyl bromide, commodity groups and US EPA must work to ensure that all pesticides used on California strawberries are acceptable to importing countries. Because the Codex process takes up to eight years to clear a new registration, it is critical that international regulations keep pace with the development of new reduced risk products as mandated by FQPA.

Work Group Recommendations for International Trade/Codex Concerns

REGULATORY	• Work with the registrant community and the California Strawberry Commission to insure MRLs (maximum residue limits) are in place for products in the registration process at US EPA • Determine the international MRL status of Switch® and Elevate®

WORKER PROTECTION

As products move through the US EPA registration and re-registration phases, attention to occupational risk will increase. Considerable hand and field labor is required to produce and harvest the strawberry crop. It is therefore critical to identify products and practices that may be of concern to regulators and to suggest appropriate risk mitigation practices. Descriptions of worker activities are provided in Appendix 3.

Work Group Recommendations for Worker Protection

KEY WORKER RISK ISSUES	• Provide accurate data to US EPA on worker exposures, time performing activities, etc. for risk assessments • Educate growers and workers on techniques, equipment, and personal protective equipment (PPE) for alternatives to MB and/or other fumigants
REGULATORY ACTIONS AND ISSUES	• Ensure all necessary testing is done to establish appropriate REIs and PHIs
EDUCATIONAL ISSUES	• Educate public/legislators on need for hand weeding in strawberries

FOOD SAFETY

Strawberries must be free of any micro-organisms that cause human illness. Pathogens of concern in strawberries include *E. coli*, *Salmonella, Listeria,* and *Cyclospora.* Protecting the safety of California strawberries requires a comprehensive and coordinated effort throughout the entire food production and transportation system. The responsibility to safeguard the fruit is shared among the growers, farm workers, packers, shippers, transporters, importers, wholesalers, retailers, government agencies, and consumers.

Contamination by these organisms occurs mainly through water (in the field or packing house), through exposure to manure or municipal bio-solids, through inadequate worker hygiene, and through poor sanitary conditions at packing facilities and in transport. Growers, packers, and shippers should consider the physical characteristics of the produce and the potential sources of microbial contamination associated with their operations, and determine which combination of good agricultural and management practices limits contamination most cost effectively.

RESEARCH	• Determine the post-freezing survival of pathogens in soil, on fruit, and in storage • Determine the risk of contamination from compost
REGULATORY	• Keep the industry's quality assurance programs self-enforcing
EDUCATION	• Promote adoption of Good Agricultural Practices (GAP) • Provide training on personal hygiene and sanitation to growers, nurseries, field workers, and processing plant workers

3. CRITICAL ISSUES FOR THE CALIFORNIA STRAWBERRY INDUSTRY

The following areas were identified by the Strawberry Work Group as most critical to the sustained viability of the California strawberry industry.

RESEARCH	• Develop new methods to produce clean nursery stock • Evaluate iodomethane and other alternatives to methyl bromide • Conduct long-term research on alternatives to fumigants in production fields • Conduct long-term research on alternatives to fumigants in high and low elevation nurseries • Evaluate new materials for in-season whitefly control • Evaluate new materials and techniques to manage lygus • Develop a resistance management strategy for spider mites • Develop and evaluate herbicides for use under plastic mulches • Evaluate new materials for control of powdery mildew • Study the biology and epidemiology of *Colletotrichum* • Evaluate soil and root microbiology on nursery stock and determine their impact on transplant performance • Develop improved pest management and crop production methodologies for organic growers • Continue plant breeding projects to improve horticultural and pest resistance characteristics of strawberries for organic and non-organic production systems
REGULATORY	• Obtain a Critical Use Exemption (CUE) for methyl bromide • Register alternatives to methyl bromide • Obtain an Experimental Use Permit (EUP) for iodomethane • Work with CDPR to develop relief for township caps for 1,3-D • Harmonize international tolerances and MRLs • Harmonize fumigant permit conditions among California counties • Reduce carbaryl bait PHI • Register materials for lygus, whiteflies, and powdery mildew • Register organophosphate and carbamate alternatives as soon as possible; utilize the IR-4 priority system for research on reduced risk materials • Harmonize Cal/EPA and US EPA registrations to hasten new product registrations • Develop best management practices (BMPs) and environmental mitigation measures for environmental issues • Identify potential trade irritants as early as possible in the research and registration process; insure there are no conflicts with provisions of NAFTA or Codex
EDUCATION	• Educate growers and PCAs on methyl bromide alternatives • Educate the public and regulators on the need for fungicides • Educate growers and regulators on resistance management • Educate regulators on systems approaches to using fumigants such as methyl bromide on strawberries • Educate applicators and growers on safe and efficient application techniques • Educate growers, PCAs, and commodity members on the use of best management practices (BMPs) to protect and improve water and soil quality • Educate the urban and agricultural communities on good agriculture practices (GAPs) for food safety issues • Educate the public on the nutritional values of California grown strawberries and their high level of food safety and quality

REFERENCES

Publications

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Postharvest Technology of Horticultural Crops, Second edition, 1992, UC ANR Publication 3311

Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables, 1999, USDA - Food and Drug Administration. Centers for Disease Control and Prevention

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California Strawberry Commission website and links *www.calstrawberry.com/default.asp*

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Pest Management and Crop Profile: Strawberries in California. 2001, http://pestdata.ncsu.edu/cropprofiles/docs/castrawberries.html

IR-4 Project website *http://pestdata.ncsu.edu/ir-4/index.cfm*

Western Regional Pest Management Center website *http://www.wrpmc.ucdavis.edu/index.html*

APPENDICES

1. 2002 California Strawberry Production Statistics

County	Harvest Area (Acres)	Yield (Tons/Acre)	Production (Tons)	Total Value ($)
Fresh Market				
Los Angeles	122	23.0	2,800	2,807,000
Monterey	6,725	30.4	204,496	223,044,000
Sacramento	92	6.5	598	1,196,000
San Diego	698	24.3	16,961	23,237,100
San Luis Obispo	720	21.5	15,509	16,816,000
Santa Barbara	3,725	21.4	79,588	87,015,900
Ventura	5,708	28.3	161,356	244,564,000
Fresh Market State Totals	**17,790**	**Average 22.2**	**481,308**	**598,680,000**
Processing				
Monterey	255	30.5	7,764	3,805,000
San Diego			7,120	4,556,500
Santa Barbara			42,093	28,791,600
Ventura	2,874	28.3	81,257	53,360,000
Processing State Totals	**3,129**	**Average 29.4**	**138,234**	**90,513,100**
Unspecified				
Merced	284	11.0	3,124	3,198,000
Orange	1,965	23.1	45,392	52,608,700
Placer	30			324,000
Riverside	236	9.0	2,125	3,623,800
San Bernardino	184	23.8	4,384	4,075,600
San Mateo	16			297,000
Santa Clara	80	14.5	1,157	1,478,000
Santa Cruz	3,586	25.6	91,802	107,408,000
Unspecified State Totals	**6,381**	**17.8**	**147,984**	**173,013,100**
STATE TOTALS	**27,300**	**Average 26.9**	**767,526**	**843,003,700**

Source: County Agricultural Commissioners' Data

2. Crop Development, Cultural Practices, and Pest Management Activities in California Strawberries

South Coast Production Region

Crop Development	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Transplanting							■			■		
Mulching								■		■		
Bloom	■	■	■	■	■	■	■			■	■	■
Pollination	■	■	■	■	■	■	■			■	■	■
Fruit Development	■	■	■	■	■	■	■			■	■	■
Harvest	■	■	■	■	■	■	■			■	■	■
Cultural Practices	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Cultivation	■	■	■	■	■	■					■	■
Irrigation	■	■	■	■	■	■	■	■	■	■	■	■
Fertilizer Applications	■	■	■	■	■	■				■	■	■
Pest Management Activities	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Soil Sampling							■	■	■			
Water Analysis							■	■	■			
Scouting	■	■	■	■	■	■	■	■	■	■	■	■
Hot Water Treatments						■	■	■	■			
Soil Fumigation							■	■	■			
Insecticide Applications	■	■	■	■	■	■		■	■	■	■	■
Fungicide Applications	■	■	■	■	■	■	■	■	■	■	■	■
Herbicide Applications									■	■	■	
Vertebrate Control	■	■	■	■	■					■	■	■
Hand Weeding	■	■	■	■	■	■		■	■	■	■	■

Data based on collective field observations and experiments

2. Crop Development, Cultural Practices, and Pest Management Activities in California Strawberries (continued)

Oxnard Plain Production Region

Crop Development	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Transplanting												
Mulching												
Bloom												
Pollination												
Fruit Development												
Harvest												
Cultural Practices	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Cultivation												
Irrigation												
Fertilizer Applications												
Pest Management Activities	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Soil Sampling												
Water Analysis												
Scouting												
Soil Fumigation												
Nematicide Applications												
Insecticide Applications												
Fungicide Applications												
Herbicide Applications												
Vertebrate Control												
Hand Weeding												

Data based on collective field observations and experiments

2. Crop Development, Cultural Practices, and Pest Management Activities in California Strawberries (continued)

Santa Maria Production Region

Crop Development	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Transplanting												
Mulching												
Bloom												
Pollination												
Fruit Development												
Harvest												
Cultural Practices	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Cultivation												
Irrigation												
Fertilizer Applications												
Pest Management Activities	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Soil Sampling												
Water Analysis												
Scouting												
Soil Fumigation												
Insecticide Applications												
Fungicide Applications												
Herbicide Application												
Vertebrate Control												
Hand Weeding												

Data based on collective field observations and experiments

2. Crop Development, Cultural Practices, and Pest Management Activities in California Strawberries (continued)

Central Coast Production Region

Crop Development	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Transplanting										■	■	
Mulching	■	■										■
Bloom			■	■	■	■	■	■	■	■	■	
Pollination			■	■	■	■	■	■	■	■	■	
Fruit Development			■	■	■	■	■	■	■	■	■	
Harvest			■	■	■	■	■	■	■	■	■	
Cultural Practices	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Cultivation	■	■	■	■							■	■
Irrigation	■	■	■	■	■	■	■	■	■	■	■	■
Fertilizer Applications	■	■	■	■	■	■	■	■	■	■	■	
Pest Management Activities	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Soil Sampling						■	■					
Water Analysis	■					■						
Scouting	■	■	■	■	■	■	■	■	■	■	■	
Degree-Day Calculations			■	■	■	■	■	■				
Soil Fumigation						■	■	■	■			
Nematicide Applications						■	■	■	■			
Insecticide Applications		■	■	■	■	■	■	■	■	■	■	
Fungicide Applications			■	■	■	■	■	■	■	■		
Herbicide Applications								■	■	■	■	
Vertebrate Control		■	■	■	■	■	■	■	■			
Hand Weeding	■	■	■	■	■	■	■	■	■		■	■

Data based on collective field observations and experiments

3. Worker Activities in California Strawberry Production

The following information is approximate and varies by season, region, operation size, grower, worker, and PCA. Please refer to Appendices 2 and 4 to determine when these practices occur. The following information is based on a 100-acre farming operation.

Description of Cultural Practices

Cultural Practices	Description of Related Activities	Hrs/Day/ Person	Size of Crew	People/ Acre	Acres/ Day/ Person
Bed preparation	List (shape) beds and prepare soil for transplanting and placement of plastic mulch on top of soil	5	2	<1	18
	Pre-plant fertilizer application	5	6	<1	6
	Install drip tape by hand by laying tape and then burying in plant rows	5	6	<1	6
Transplanting	Performed by hand	8	80	<1	<1
Irrigation	Sprinkler or drip, dependent upon operation and time of season	4	2	<1	15
Fertilizer Application	Routinely done through drip irrigation system after plants are established	4	2		15
Harvest	Mature berries are harvested by hand several times throughout the season	8	200		<1

Description of Pest Management Activities

Pest Management Activities	Description of Related Activities	Hrs/Day/ Person	Size of Crew	People/ Acre	Acres/ Day/ Person
Soil Sampling	Taken by hand with soil probe or shovel, for analysis of composition, nutrients, and insect pests	1	1	<1	100
Water Analysis	Taken by hand to determine water quality (NPK, salinity, nitrates, micros, etc.)	1	1	<1	
Scouting	Row-by-row observation of plant health to examine growth, berry development, pest problems, etc; requires expertise in pests, diseases, and quality	2	1	<1	50
Mulching and Soil Fumigation	Warms beds and prevents weeds; 4 drivers and 8 riders lay plastic mulch over planting beds and shovel dirt over edges; fumigation controls weeds, insects, nematodes, and diseases, and promotes vigorous growth	-	13	<1	1.5
Insecticide Applications	Mechanically applied, usually with sprayer attached to tractor	1	5	<1	6
Fungicide Applications	Mechanically applied, usually with sprayer attached to tractor	1	5	<1	6
Herbicide Applications	Mechanically applied, usually with sprayer attached to tractor	1	5	<1	6
Vertebrate Control	Various tools such as baits, poisons, trapping, exclusion techniques.	1	1	<1	NA
Hand Weeding	Row-by-row hoeing to remove weeds	8	6	<1	6

4. Seasonal Pest Occurrence in California Strawberries

South Coast Production Region

PESTS	J	F	M	A	M	J	J	A	S	O	N	D
Insects and Mites												
Two-Spotted Spider Mite	■	■	■	■	■			■	■	■	■	■
Aphids	■	■	■	■							■	■
Western Flower Thrips			■	■	■	■						
Cutworms								■	■	■	■	■
Beet Armyworm	■	■	■	■				■	■	■	■	■
Whiteflies	■	■	■	■	■	■	■	■	■	■	■	■
Cabbage Looper				■	■	■				■	■	
Corn Earworm			■	■	■	■				■	■	■
Diseases												
Botrytis	■	■	■	■	■	■	■			■	■	■
Verticillium Wilt	■	■	■							■	■	■
Rhizopus Fruit Rot				■	■							
Powdery Mildew	■	■	■	■	■	■				■	■	■
Phytophthora Crown Rot	■	■	■							■	■	■
Phytophthora Root Rot	■	■	■	■	■	■				■	■	■
Common Leaf Spot	■	■	■							■	■	■
Anthracnose (*Colletotrichum*)	■	■	■	■						■	■	■
Leather Rot	■	■	■									
Mucor Fruit Rot				■	■							
Red Stele	■	■	■	■						■	■	■
Weeds												
Nettle	■	■								■	■	■
Chickweed	■	■								■	■	■
Mallow	■	■	■	■	■					■	■	■
Lambsquarters	■	■								■	■	■
Pigweed	■	■								■	■	■
Pinappleweed	■	■								■	■	■
Bindweed	■	■								■	■	■
Annual Grasses				■	■	■						
Vertebrates												
Birds	■	■	■	■								■

Data based on collective field observations and experiments

4. Seasonal Pest Occurrence in California Strawberries (continued)

Oxnard Plain Production Region

PESTS	J	F	M	A	M	J	J	A	S	O	N	D
Insects and Mites												
Two-Spotted Spider Mite	■	■	■	■	■			■	■	■	■	■
Lygus Bugs								■	■	■	■	
Aphids	■	■	■	■							■	■
Western Flower Thrips			■	■	■				■	■		
Cutworms		■	■	■	■	■				■	■	■
Beet Armyworm				■	■			■	■	■	■	
Whiteflies	■	■	■	■	■	■	■	■	■	■	■	■
Cabbage Looper			■	■				■	■	■		
Corn Earworm				■	■			■	■	■		
Diseases												
Botrytis	■	■	■	■	■	■		■	■	■	■	■
Verticillium Wilt	■	■	■	■						■	■	■
Rhizopus Fruit Rot				■	■	■						
Powdery Mildew	■	■	■	■	■	■		■	■	■	■	■
Phytophthora Crown Rot											■	■
Phytophthora Root Rot											■	■
Common Leaf Spot											■	■
Anthracnose (*Colletotrichum*)								■	■	■	■	■
Leather Rot	■	■	■	■						■	■	■
Mucor Fruit Rot				■	■	■						
Red Stele											■	■
Weeds												
Nettle	■	■	■							■	■	■
Chickweed	■	■	■							■	■	■
Mallow	■	■	■	■	■	■			■	■	■	
Lambsquarters			■	■	■	■						
Pigweed			■	■	■	■						
Pinappleweed			■	■	■	■						
Bindweed			■	■	■	■			■	■		
Annual Grasses			■	■	■	■						
Vertebrates												
Birds	■	■	■	■	■							

Data based on collective field observations and experiments

4. Seasonal Pest Occurrence in California Strawberries (continued)

Santa Maria Production Region

PESTS	J	F	M	A	M	J	J	A	S	O	N	D
Insects and Mites												
Two-Spotted Spider Mite		■	■	■	■	■						
Lygus Bugs				■	■	■	■					
Cyclamen Mite				■	■	■	■					
Aphids		■	■	■	■	■						
Western Flower Thrips				■	■	■						
Cutworms	■											■
Beet Armyworm					■	■						
Cabbage Looper		■	■	■								
Corn Earworm		■	■	■								
Diseases												
Botrytis		■	■	■	■	■						
Verticillium Wilt	■	■	■	■	■	■	■	■		■	■	■
Rhizopus Fruit Rot			■	■								
Powdery Mildew			■	■	■	■	■	■				
Phytophthora Crown Rot	■	■	■	■								
Phytophthora Root Rot	■	■	■	■								
Common Leaf Spot	■	■										
Anthracnose (*Colletotrichum*)	■	■									■	■
Leather Rot	■	■	■	■	■	■	■	■		■	■	■
Mucor Fruit Rot									■	■	■	
Red Stele	■	■	■	■	■	■	■			■	■	■
Weeds												
Nettle	■	■	■							■	■	■
Chickweed	■	■	■							■	■	■
Mallow	■	■	■	■	■	■	■	■	■	■	■	■
Lambsquarters	■	■	■	■	■	■	■	■	■	■	■	■
Pigweed	■	■	■	■	■	■	■	■	■	■	■	■
Pinappleweed	■	■	■	■	■	■	■	■	■	■	■	■
Bindweed	■	■	■	■	■	■	■	■	■	■	■	■
Annual Grasses	■	■	■	■	■	■	■	■	■	■	■	■
Vertebrates												
Birds		■	■	■	■	■						

Data based on collective field observations and experiments

4. Seasonal Pest Occurrence in California Strawberries (continued)

Central Coast Production Region

PESTS	J	F	M	A	M	J	J	A	S	O	N	D
Insects and Mites												
Two-Spotted Spider Mite			■	■	■	■	■	■	■	■		
Lygus Bugs				■	■	■	■	■	■	■		
Cyclamen Mite			■	■								
Aphids	■	■	■									
Root Weevils		■	■									
Western Flower Thrips					■	■	■	■	■			
Cutworms			■	■	■	■	■	■	■	■		
Beet Armyworm			■	■	■	■	■	■	■	■		
Whiteflies		■	■	■	■						■	■
Cabbage Looper				■	■	■	■	■	■	■		
Corn Earworm				■	■	■	■	■	■	■		
Diseases												
Botrytis			■	■	■	■	■	■	■	■		
Verticillium Wilt							■	■	■	■		
Rhizopus Fruit Rot						■	■	■				
Powdery Mildew			■	■	■	■	■	■	■	■		
Phytophthora Crown Rot							■	■	■			
Phytophthora Root Rot							■	■	■			
Common Leaf Spot		■	■									
Anthracnose (*Colletotrichum*)		■	■									
Leather Rot				■	■	■						
Mucor Fruit Rot							■	■				
Red Stele						■	■	■				
Weeds												
Nettle	■	■	■	■	■	■	■	■	■	■	■	■
Chickweed	■	■	■	■	■	■	■	■	■	■	■	■
Mallow	■	■	■	■	■	■	■	■	■	■	■	
Lambsquarters	■	■	■	■	■	■	■	■	■	■		
Pigweed	■	■	■	■	■	■	■	■	■	■		
Pinappleweed	■	■	■	■	■	■	■	■	■	■		
Bindweed	■	■	■	■	■	■	■	■	■	■		
Annual Grasses	■	■	■	■	■	■	■	■	■	■	■	■
Vertebrates												
Birds				■	■	■	■	■	■			

Data based on collective field observations and experiments

5. Efficacy of Insect Management Tools Used in California Strawberries

Primary Insects

Efficacy Ratings: E = Excellent, G = Good, F = Fair, P = Poor/None, R = Known Resistance

REGISTERED CHEMICAL PRODUCT	TRADE NAME	Two-spotted Spider Mites	Lygus Bugs	Cyclamen Mites	Aphids	Root Weevils	Western Flower Thrips	Cutworms	Beet Armyworms	Whiteflies
Abamectin	Agri-mek®	E	P	G	P	P	F	P	P	F
Azadirachtin	Neemix®	P	P-F	P	F-E	P	F	P	P	P
Azinphos-methyl	Guthion®	P	E	P	G	G	G	G	G	
Bacillus thuringiensis	Bt-various	P	P	P	P	P	P	F	F	P
Bifenthrin	Brigade®	E	F-E	F-G	F	F-G	F	F	F	F
Bifenzate	Acramite®	E	P	P	P	P	P	P	P	P
Carbaryl	Sevin®	P	F	P	F	F	P	G	G	P
Chloropicrin	Chloropicrin	F	P	P	P	E	P	F	P	P
Chlorpyrifos	Lorsban®	P	P	P	F-G	G	P	G	F	P
Cinnamaldehyde	Valero®	F	P	P	F	P	P	P	P	P
Cryolite	Cryolite	P	P	P	P	P	P	P	P	P
Diazinon	various	P	F	P	G	F	F	G	F-G	P
Dicofol	Kethane®	P-F	P	G	P	P	P	P	P	P
Endosulfan	Thiodan®	F	G	E	G	F	F	F	F	F-G
Fenbutatin-oxide	Vendex®	P-F	P	P-F	P	P	P	P	P	P
Fenpropathrin	Danitol®	F-G	F-E	F-G	F	F-G	F-E	F	F	F
Hexythiazox	Savey®	G*	P	P	P	P	P	P	P	P
Imidacloprid	Admire®	P	F	P	G-E			P	P	F-E
Malathion	various	P	P-G	P	G	P	F	F	P	F
Metaldehyde	Deadline®	P	P	P	P	P	P	P	P	P
Metam Sodium	Metam Sodium	P	P	P	P	P	P	P	P	P
Methomyl	Lannate®	P	E**	P	F-E		F-E	G-E	G-E	G
Methyl Bromide	Methyl Bromide	F	P	P	P	E	P	P	P	P
Naled	Dibrom®	P	F	P	G	P	F	F	F	P
Narrow Range Oil	various	F-G	P	P	F	P	P	P	P	P-F
Potash Soap	M-Pede®	F	P	P	F	P	P	P	P	P
Pyrethrin	various	P	P	P	P	P	P	P	F	P
Rotenone	Rotenone	F	P	P	F-G	P	P	P	F	P
Spinosad	Success®	P	P	P	P	P	E-G	F	G	P

Data based on collective field observations and experiments

5. Efficacy of Insect Management Tools Used in California Strawberries (continued)

Primary Insects

Efficacy Ratings: E = Excellent, G = Good, F = Fair, P = Poor/None, R = Known Resistance

UN-REGISTERED CHEMICAL PRODUCT	TRADE NAME	Two-spotted Spider Mites	Lygus Bugs	Cyclamen Mites	Aphids	Root Weevils	Western Flower Thrips	Cutworms	Beet Armyworms	Whiteflies
Buprofezin	Applaud®	P	P	P	P	P	P	F	F	F-G
Etoxizole	Baroque®	E	P		P	P	P	P	P	P
Imidacloprid	Admire®	P	F	P	F-G	P		P	P	G-E
Lambda cyhalothrin	Warrior®				F-G			G-E	G-E	
Methoxyfenozide	Intrepid®	P								
Milbemectin	Mesa®	E	P	F-G	P	P	F	P	P	P
Pyridaben	Pyramite®	F-G	P	P	P	P	P	P	P	P
Pyriproxifen	Esteem®	P		P		P				G-E
Thiamethoxam	Actara®	P	F	P	F-G	P		P	P	G

Data based on collective field observations and experiments

5. Efficacy of Insect Management Tools Used in California Strawberries (continued)

Primary Insects

Efficacy Ratings: E = Excellent, G = Good, F = Fair, P = Poor/None, R = Known Resistance

NON-CHEMICAL MANAGEMENT TOOL	Two-spotted Spider Mites	Lygus Bugs	Cyclamen Mites	Aphids	Root Weevils	Western Flower Thrips	Cutworms	Beet Armyworms	Whiteflies
Field Placement	P-E	F	P-F	P	P-G	P	P-G	P	F-E
Field Monitoring	E	E	G	F	P	G	P	G	G
Use of Economic Thresholds	E	E	P	P	P	G	P	P	P
Use of Models	P	G	P	P	P	P	P	F	P
Sanitation	P	F	G-E	P	F	P	P	P	G
Biological Control	G	P	P	F	P	P	P	F	P
Weed-Host Control	P	G	P	P	F	P	P	P	F-G
Flooding	P	P	P	P	P	P	P	P	P
Barriers	P	P	P	P	P	P	P	P	P
Ripe Fruit Removal	P	P	P	P	F	P	F	P	P
Crop Rotation	P	P	P	P	F	P	F	P	P
Dust Reduction	F	P	P	P	P	P	P	P	P
Soil Solarization	P	P	P	P	P	P	P	P	P
Plastic Covers	P	G	P	P	P	P	P	F	P
Sticky Barriers	P	P	P	P	F	P	P	P	P
Vacuuming	P	F	P	P	P	P	P	P	P
Topping	P	P	P	P	P	P	P	P	F
Certified Transplants	P	P	P	P	P	P	P	P	P
Resistant Varieties	F	P	P	P	P	P	P	P	P
Rain									E

Data based on collective field observations and experiments

5. Efficacy of Insect Management Tools Used in California Strawberries (continued)

Secondary Insects

Efficacy Ratings: E = Excellent, G = Good, F = Fair, P = Poor/None, R = Known Resistance

REGISTERED CHEMICAL PRODUCT	TRADE NAME	Cabbage Looper	Corn Earworm	European Earwig	Hoplia Beetle	White Grub	Garden Tortrix	Saltmarsh Caterpillar	Vinegar Fly
Abamectin	Agri-mek®	P	P-F	P	P	P	P	P	P
Azadirachtin	Neemix®	F	F	P	P	P	P	P	P
Azinphos-methyl	Guthion®	G	F	P	E	G	F	G	F
Bacillus thuringiensis	Bt	E	F	P	P	P	F	F	P
Bifenthrin	Brigade®	G	F	P	P	P	F	F	G-E
Bifenzate	Acramite®	P	P	P	P	P	P	P	P
Carbaryl	Sevin®	F	F	F	P	P	P	P	P
Chloropicrin	Chloropicrin	P	P	P	E	E	P	P	P
Chlorpyrifos	Lorsban®	G	G	G	G	G	G	G	F
Cinnamaldehyde	Valero®	P	P	P	P	P	P	P	P
Cryolite	Cryolite	P	F	P	P	P	G	F	P
Diazinon	Diazinon	G	F	G	F	F	G	F	P
1,3-Dichloropropene	Telone®	P	P	P			P	P	P
Dicofol	Kethane®	P	P	P	P	P	P	P	P
Endosulfan	Thiodan®	G	F	F			G	F	P
Fenbutatin-oxide	Vendex®	P	P	P	P	P	P	P	P
Fenpropathrin	Danitol®	G	F	P	P	P	F	F	F-G
Hexythiazox	Savey®	P	P	P	P	P	P	P	P
Imidacloprid	Admire®	P	P	P			P	P	P
Malathion	Malathion	F	F	F	P	P	G	G	P-G
Metaldehyde	Deadline®	P	P	P	P	P	P	P	P
Metam Sodium	Vapam®	P	P	P	F	F	P	P	P
Methomyl	Lannate®	G-E	E	G	F	E	E	F	G
Methyl Bromide	Methyl Bromide	P	P	P	E	E	P	P	P
Naled	Dibrom®	F	F	P	P	P	F	P	F
Narrow Range Oil	various	P	P	P	P	P	P	P	P
Potash Soap	M-Pede®	P	P	P	P	P	P	P	P
Pyrethrin	various	F	P	P	P	P	P	P	F
Rotenone	Rotenone	P	P	P	P	P	P	P	P
Spinosad	Success®	G	G	P	P	P	G	G	P

Data based on collective field observations and experiments

5. Efficacy of Insect Management Tools Used in California Strawberries (continued)

Secondary Insects

Efficacy Ratings: E = Excellent, G = Good, F = Fair, P = Poor/None, R = Known Resistance

UN-REGISTERED CHEMICAL PRODUCT	TRADE NAME	Cabbage Looper	Corn Earworm	European Earwig	Hoplia Beetle	White Grub	Garden Tortrix	Saltmarsh Caterpillar	Vinegar Fly
Buprofezin	Applaud®		F						
Etoxizole	Baroque®	P	P	P	P	P	P	P	P
Lambda cyhalothrin	Warrior®	E	G						G
Pyridaben	Pyramite®	P	P	P	P	P	P	P	P

Data based on collective field observations and experiments

5. Efficacy of Insect Management Tools Used in California Strawberries (continued)

Secondary Insects

Efficacy Ratings: E = Excellent, G = Good, F = Fair, P = Poor/None, R = Known Resistance

NON-CHEMICAL MANAGEMENT TOOL	Cabbage Looper	Corn Earworm	European Earwig	Hoplia Beetle	White Grub	Garden Tortrix	Saltmarsh Caterpillar	Vinegar Fly
Field Placement	P	P	P	F-E	E	P	P	P
Field Monitoring	F	G	F	F	F	P	P	G
Use of Economic Thresholds	P	F	P	P	P	P	P	P
Use of Models	P	G	P	P	P	P	P	F
Sanitation	P	P	F-G	F	P	P	P	E
Biological Control	G	F	P	P	P	P	P	P
Weed-Host Control	P	P	P	F	F	P	P	P
Flooding	P	P	P	P	P	P	P	P
Barriers	P	P	P	P	P	P	F	G
Ripe Fruit Removal	P	P	P	P	P	P	P	E
Crop Rotation	P	P	P	G	G	P	P	P
Dust Reduction	P	P	P	P	P	P	P	P
Soil Solarization	P	P	P	F	F	P	P	P
Plastic Covers	F	F	P	P	P	F	F	P
Sticky Barriers	P	P	P	P	P	P	P	P
Vacuuming	P	P	P	P	P	P	P	P
Topping	P	P	P	P	P	P	P	P
Certified Transplants	P-E	P	P	P	P	P	P	P
Resistant Varieties	P	P	P	P	P	P	P	P

Data based on collective field observations and experiments

6. Relative Toxicity of Insect Management Tools to Beneficial Organisms in California Strawberries

Toxicity Ratings: U = Unknown, O = No Effect, S = Slightly Toxic, M = Moderately Toxic, H = Highly Toxic

REGISTERED CHEMICAL PRODUCT	TRADE NAME	Big-eyed Bugs	Minute Pirate Bugs	Lacewings	Dusty Wings	Damsel Bugs	Cecidomyid Fly	Lady Bird Beetles	Predacious Mites	Spider Mite Destroyers	Spiders
Abamectin	Agri-mek®	M	M	S	M	M			M		
Azadirachtin	Neemix®	M	M	M	M	M				M	
Azinphos-methyl	Guthion®								M		
Bacillus thuringiensis	Bt	O	O	O	O	O	O	O	O	O	O
Bifenthrin	Brigade®	H	H	H	H	H	H	H	H	H	H
Bifenzate	Acramite®	O	O	O	O	O	O	O	O	O	O
Carbaryl	Sevin®								H		
Chloropicrin	Chloropicrin	O	O	O	O	O	O	O	O	O	O
Chlorpyrifos	Lorsban®								M		
Cinnamaldehyde	Valero®	M	M	S	S	M		O	M	O	S
1,3-Dichloropropene	Telone®	O	O	O	O	O	O	O	O	O	O
Dicofol	Kethane®								H		
Endosulfan	Thiodan®								H		
Fenbutatin-oxide	Vendex®	S	S	O	S	S	O	O	S	O	S
Fenpropathrin	Danitol®	H	H	H	H	H	H	H	H	H	H
Hexythiazox	Savey®	O	O	O	O	O		O	O	O	
Malathion	Malathion								M		
Metaldehyde	Deadline®	O	O	O	O	O	O	O	O	O	O
Metam Sodium	Metam Sodium	O	O	O	O	O	O	O	O	O	O
Methomyl	Lannate®	H	H	H	H	H	H	H	H	H	H
Methyl Bromide	Methyl Bromide	O	O	O	O	O	O	O	O	O	O
Naled	Dibrom®								M		
Narrow Range Oil	various	S	M	M	S	S	M	O	M	O	S
Potash Soap	M-Pede®	M	M	M	M	M		S	M	S	S
Pyrethrin	various								M		
Rotenone	various	H	H	H					H		
Spinosad	Success®								S		

Data based on collective field observations and experiments

6. Relative Toxicity of Insect Management Tools to Beneficial Organisms in California Strawberries (continued)

Toxicity Ratings: U = Unknown, O = No Effect, S = Slightly Toxic, M = Moderately Toxic, H = Highly Toxic

UN-REGISTERED CHEMICAL PRODUCT	TRADE NAME	Big-eyed Bugs	Minute Pirate Bugs	Lacewings	Dusty Wings	Damsel Bugs	Cecidomyid Fly	Lady Bird Beetles	Precarious Mites	Spider Mite Destroyers	Spiders
Etoxizole	Baroque®	O	O	O	O	O			O		
Iodomethane	Midas®	O	O	O	O	O	O	O	O	O	O
Milbemectin	Mesa®	M	M	S	M	M			M		
Pyridaben	Pyramite®	M	M	M	M	M			H		

Data based on collective field observations and experiments

7. Efficacy of Weed Management Tools Used in California Strawberries

Efficacy Ratings: E = Excellent, G = Good, F = Fair, P = Poor/None, R = Known Resistance

PRODUCT	TRADE NAME	Bluegrass	California Burr Clover	Chickweed	Groundsel	Knotweed	Little Mallow	Cudweed	Filaree	Shepherd's Purse	Yellow Nutsedge
Chemical											
Chloropicrin	Chloropicrin	G	F	G	F	G	F	F	P	F	P
Clethodim	Select®/ Prism®	G	P	P	P	P	P	P	P	P	P
Clopyralid	Stinger®	P	G	F	G	P	P	G	F	F	P
Flumioxazin	Chateau®	G	G	G			E				P
Metam Sodium	Metam Sodium	g	F	G	F	G	F	G	F	G	F
Methyl Bromide	Methyl Bromide	G	F	E	F	E	F	G	F	E	G
Napropamide	Devrinol®	G	F	G	G	G	F	F	G	F	P
Oxyfluorfen	Goal®	F	F	P	G	F	E	P	G	F	P
Paraquat Dichloride	Gramoxone®	F	F	G	G	F	P	P	F	F	P
Sethoxydim	Poast®	P	P	P	P	P	P	P	P	P	P
Non-chemical											
Hand Weeding		G	G	G	G	G	G	G	G	G	G
Mulches, Organic		F	F	F	F	F	F	P	F	F	P
Mulches, Synthetic Opaque			G	G	G	G	G	G	G	G	G
Solarization with Mulches			F	F	F	F	F	F	F	F	F
Mechanical Weeding		F	F	F	F	F	F	F	F	F	F

Data based on collective field observations and experiments

8. Efficacy of Disease Management Tools Used in California Strawberries

Efficacy Ratings: E = Excellent, G = Good, F = Fair, P = Poor/None, R = Known Resistance

Registered Chemical Products	Trade Name	*Botrytis* Fruit Rot	*Verticillium* Wilt	*Rhizopus* Fruit Rot	Powdery Mildew	*Phytophthora* Crown Rot	*Phytophthora* Root Rot	Common Leaf Spot	Anthracnose Root Rot	Leather Rot	*Mucor* Fruit Rot	Red Stele	Angular Leaf Spot
Ampelomyces	AQ10	P	P	P	F	P	P	P	P	P	P	P	
Azoxystrobin	Quadris®	F	P	P	G	P	P	P	E	P	P	P	
Captan	Captan	G	P	P	P	P	P	F	G	P	P	P	
Chitosan	Elexa®	P	P	P	F	P	P	P	P	P	P	P	
Chloropicrin	Chloropicrin	P	E	P	P	G-E	G	P	G	G	P	G	
Chlorothalonil	Bravo®	P	P	P	P	P	P	G	F	P	P	P	
Cyprodinil/ Fludioxonil	Switch®	E	P	P	F	P	P	P	P	P	P	P	
1,3-Dichloropropene	Telone®	N-P	G	N	N	G	G-E	N	G	N	N	G	N
Fenhexamid	Elevate®	E	P	P	F	P	P	P	P	P	P	P	
Fixed Copper	various	F	P	P	F	P	P	F	P	P	P	P	G
Fosetyl-al	Aliette®	P	P	P	P	G	G	P	P	G	P	G	
Harpin protein	Messenger®	P	P	P	P	P	P	P	P	P	P	P	
Iprodione	Rovral®	R-E	P	P	P	P	P	P	P	P	P	P	
Mefenoxam	Ridomil® Gold	P	P	P	P	G	G	P	P	P	P	G	
Metam Sodium	Metam Sodium	P	P	P	P	F	F	P	P	F	P	F	
Methyl Bromide	Methyl Bromide	E	E	E	E	E	E	E	E	E	E	E	
Micronized Sulfur	various	P	P	P	G	P	P	P	P	P	P	P	
Myclobutanil	Rally®	P	P	P	R-E	P	P	P	F	P	P	P	
Narrow Range Oil	various	G	P	P	E	P	P	P	P	P	P	P	
Potash Soap	M-Pede®	P	P	P	G	P	P	P	P	P	P	P	
Potassium Bicarbonate	Kaligreen®	P	P	P	G	P	P	P	P	P	P	P	
Thiophanate-methyl	Topsin®	R-G	P	P	G	P	P	P	P	P	P	P	
Thiram	Thiram	G	P	P	P	P	P	P	F	P	P	P	

Data based on collective field observations and experiments

8. Efficacy of Disease Management Tools Used in California Strawberries (continued)

Efficacy Ratings: E = Excellent, G = Good, F = Fair, P = Poor/None, R = Known Resistance

UN-REGISTERED CHEMICAL PRODUCT	TRADE NAME	*Botrytis* Fruit Rot	*Verticillium* Wilt	*Rhizopus* Fruit Rot	Powdery Mildew	*Phytophthora* Crown Rot	*Phytophthora* Root Rot	Common Leaf Spot	Anthracnose Root Rot	Leather Rot	*Mucor* Fruit Rot	Red Stele	Angular Leaf Spot
Dazomet	Basamid®	P	P	P	P	F	F	P	F	P	P	F	
Fluidioxonil	Medallion®	E	P	P	P	P	P	P	P	P	P	P	
Pyraclostrobin	Cabrio®	F	P	P	E	P	P	P	G	P	P	P	
Quinoxyfen	Quintec®	P	P	P	E	P	P	P	P	P	P	P	
Trifloxystrobin	Flint®	F	P	P	E	P	P	P	G	P	P	P	
Triflumizone	Procure®	P	P	P	E	P	P	P	P	P	P	P	

Data based on collective field observations and experiments

8. Efficacy of Disease Management Tools Used in California Strawberries (continued)

Efficacy Ratings: E = Excellent, G = Good, F = Fair, P = Poor/None, R = Known Resistance

NON-CHEMICAL MANAGEMENT TOOL	*Botrytis* Fruit Rot	*Verticillium* Wilt	*Rhizopus* Fruit Rot	Powdery Mildew	*Phytophthora* Crown Rot	*Phytophthora* Root Rot	Common Leaf Spot	Anthracnose Root Rot	Leather Rot	*Mucor* Fruit Rot	Red Stele	Angular Leaf Spot
Canopy Size	F	P	P	P	P	P	P	P	P	P	P	
Barriers / Mulches	F-G	P-G	P	P	P	P	P	F	F	P-F	P-F	
Fertilizers	P-F	P	P	P	P-G	P	P	P	P	P	P-G	
Removal of Infected Material	F	F-G	F	P	P	P	P	P	F	P	P	
Fertilizer Limitation	P	P	P	P	P	P	P	P	P	P	P	
Irrigation Control	P	P	P	P	E	E	P	P	E	P	F	
Crop Rotation	P	F-G	P	P	G-E	G-E	P	G-E	F	P	G-E	
Field Selection	E	G	P	P	E	E	P	E	E	P	E	
Resistant Cultivars	F	G	P	E	E	E	E	E	E	P	E	
Sanitation	E-G	G	P	P	F	F	F	F	F	P	F	
Post-Harvest Cooling	E	F*	P	P	P	P	P	P	P	P	P	
Varietal Effects	E	G	P	E	E	E	P	E	E	E	E	
Leaf Removal	P	P	P	P	P	P	P	P	P	P	P-E	
Clean Stock	E	G-E	E	E	E	E	E	E	E	E	E	
Soil Removal	P	P	P	P	P	P	P	P	P	P	P	
Drip Irrigation	E	P	F-E	F-E	E	E	P-E	F-E	E	F-E	E	
Moisture Limitation	E	P	F-E	F-E	E	E	E	E	E	E	E	

Data based on collective field observations and experiments

9. Efficacy of Vertebrate Pest Management Tools Used in California Strawberries

Efficacy Ratings: E = Excellent, G = Good, F = Fair, P = Poor/None, R = Known Resistance

PEST MANAGEMENT TOOL	TRADE NAME	Birds	Ground Squirrels	Meadow Mice	Moles	Mule Deer
Chemical						
Aluminum Phosphide			E			
Zinc Phosphide			E			
Non-Chemical						
Visual Frightening Devices		F	F			P
Noisemakers		F	F			F
Traps		F	F			F
Plastic Netting		E				
Shooting		E*	E*			E*
Habitat Elimination		G	G	G	G	E
Barriers		G				F

Data based on collective field observations and experiments

* Not legal in some areas

10. Chemical Use on California Strawberries 1999-2001

Pounds of Active Ingredient (AI) Applied

PRODUCT	TRADE NAME	1999	2000	2001	3-YEAR AVERAGE
Insecticides/Acaracides/Nematicides					
Imidacloprid	Admire®	1,017	1,492	1,601	1,370
Bacillus thuringiensis	Bt (Dipel®, Javelin®)	3,553	5,939	5,575	5,022
Bifenthrin	Brigade®	521	756	979	752
Fenpropathrin	Danitol®	2,128	3,586	3,293	3,002
Metaldehyde	Deadline®	2,211	2,512	1,129	1,951
Diazinon	Diazinon	2,731	3,707	2,014	2,817
Naled	Dibrom®	12,979	10,639	8,833	10,817
Dicofol	Kelthane®	2,505	2,349	868	1,907
Methomyl	Lannate®	15,375	13,227	11,997	13,533
Chlorpyrifos	Lorsban®	7,671	3,641	5,194	5,502
Malathion	Malathion	75,936	92,816	80,420	83,057
Azadirachtin	Neemix®, Margosan®	46	122	207	125
Petroleum (Unclass.)	various	7,963	5,085	2,848	5,298
Pyrethrins + rotenone	Pyrellin® EC	56	29	51	45
Hexythiazox	Savey®	3,389	3,134	2,111	2,878
Carbaryl	Sevin®	13,033	20,195	20,867	18,031
Spinosad	Success®	0	7	1	3
Endosulfan	Thiodan®	140	10	14	54
Cinnamaldehyde	Valero®	0	4,171	1,008	1,726
Fenbutatin oxide	Vendex®	1,015	397	230	547
Herbicides					
Napropamide	Devrinol®	4,411	4,894	3,024	4,109
Oxyfluorfen	Goal®	21	7	5	11
Paraquat	Gramoxone®	1,219	1,656	715	1,196
Sethoxydim	Poast®	8	1	4	4
Glyphosate	Roundup®	272	383	539	398

Data from CDPR

10. Chemical Use on California Strawberries 1999-2001 (continued)

Pounds of Active Ingredient (AI) Applied

PRODUCT	TRADE NAME	1999	2000	2001	3-YEAR AVERAGE
Fungicides					
Fosetyl-al	Aliette® WDG	7,196	15,456	9,682	10,778
Ampelomyces quisqualis	AQ-10	0.5	0.3	0.4	0.4
Benomyl	Benlate®	10,560	9,335	7,048	8,981
Captan	Captan	181,939	188,956	170,011	180,302
Copper (Hydroxide + Salts)	various	8,646	3,699	4,200	5,515
Fenhexamid	Elevate®	7,102	23,290	23,309	17,900
Azoxystrobin	Quadris®	0	5	830	279
Myclobutanil	Rally®, Nova®	5,492	6,333	5,132	5,652
Metalaxyl-M	Ridomil® Gold	19	19	25	21
Sulfur	various	362,378	354,427	252,017	322,941
Cyprodinil/Fludioxonil	Switch®	0	0	23,309	7,770
Thiram	Thiram	79,936	84,158	68,874	77,656
Thiophanate methyl	Topsin®	84	86	1,448	539
Fumigants					
Chloropicrin	Chloropicrin	2,412,819	2,361,655	3,004,795	2,593,090
Methyl Bromide	Methyl Bromide	5,213,472	4,231,204	3,765,630	4,403,435
1,3-dichloropropene	Telone® II	537	12,989	146,350	53,292
Metam Sodium	Vapam®	132,463	63,108	85,757	93,776
Restricted Pesticides for Nursery Use Only					
Fungicides					
Chlorothalonil	Bravo®	1,202	439	729	790
Insecticides/Acaracides					
Omite 30W	Propargite®	114	6	4	42

Data from CDPR

10. Chemical Use on California Strawberries 1999-2001 (continued)

% of Strawberry Crop Acreage Treated

PRODUCT	TRADE NAME	1999	2000	2001	3-YEAR AVERAGE
Insecticides/Acaracides/Nematicides					
Imidacloprid	Admire®	3.8	6.0	12.9	7.6
Bacillus thuringiensis	Bt (Dipel®, Javelin®)	39.6	54.1	93.5	62.4
Bifenthrin	Brigade®	8.7	11.8	31.8	17.4
Fenpropathrin	Danitol®	12.2	19.7	32.7	21.5
Metaldehyde	Deadline®	4.0	5.7	5.2	5.0
Diazinon	Diazinon	6.5	6.6	9.9	7.7
Naled	Dibrom®	13.9	12.1	20.3	15.5
Dicofol	Kelthane®	4.0	3.4	3.0	3.5
Methomyl	Lannate®	21.2	16.3	33.2	23.6
Chlorpyrifos	Lorsban®	15.8	6.9	21.5	14.8
Malathion	Malathion	33.0	34.5	64.9	44.1
Azadirachtin	Neemix®, Margosan®	1.6	4.9	13.0	6.5
Petroleum (Unclass.)	various	1.7	1.1	1.3	1.3
Pyrethrins + rotenone	Pyrellin® EC	3.7	4.0	13.6	7.1
Hexythiazox	Savey®	34.3	32.9	42.3	36.5
Carbaryl	Sevin®	12.4	14.7	31.8	19.6
Spinosad	Success®	0.0	0.1	0.1	0.1
Endosulfan	Thiodan®	0.3	0.1	0.1	0.1
Cinnamaldehyde	Valero®	0.0	2.8	1.4	1.4
Fenbutatin Oxide	Vendex®	1.9	0.7	0.3	1.0
Herbicides					
Napropamide	Devrinol®	4.0	3.3	6.8	4.7
Oxyfluorfen	Goal®	0.0	0.0	0.2	0.1
Paraquat	Gramoxone®	3.5	4.2	3.9	3.9
Sethoxydim	Poast®	0.1	0.1	0.0	0.1
Glyphosate	Roundup®	0.3	0.4	1.4	0.7

Data from CDPR

10. Chemical Use on California Strawberries 1999-2001 (continued)

% of Strawberry Crop Acreage Treated

PRODUCT	TRADE NAME	1999	2000	2001	3-YEAR AVERAGE
Fungicides					
Fosetyl-al	Aliette® WDG	4.5	8.5	10.0	7.7
Ampelomyces quisqualis	AQ-10	1.3	0.9	1.4	1.2
Benomyl	Benlate®	26.2	24.6	41.0	30.6
Captan	Captan	52.4	57.5	110.4	73.4
Copper (Hydroxide + Salts)	Copper compounds	9.0	4.6	9.6	7.7
Fenhexamid	Elevate®	13.0	33.7	67.1	37.9
Azoxystrobin	Quadris®	0.0	0.0	14.9	5.0
Myclobutanil	Rally®, Nova®	42.3	43.2	81.1	55.5
Metalaxyl-M	Ridomil® Gold	0.1	0.2	0.0	0.1
Sulfur	various	50.0	53.8	96.8	66.9
Cyprodinil/Fludioxonil	Switch®			67.1	22.4
Thiram	Thiram	35.0	37.5	65.3	45.9
Thiophanate methyl	Topsin®	0.3	0.1	8.0	2.8
Fumigants					
Chloropicrin	Chloropicrin	44.7	41.5	88.8	58.3
Methyl Bromide	Methyl Bromide	44.9	41.2	82.4	56.1
1,3-dichloropropene	Telone® II	0.0	0.3	4.1	1.5
Metam Sodium	Vapam®	1.3	0.5	2.2	1.3
Restricted Pesticides for Nursery Use Only					
Fungicides					
Chlorothalonil	Bravo®	1.0	0.6	2.6	1.4
Insecticides/Acaracides					
Omite 30W	Propargite®	1.0	0.6	2.6	1.4

Data from CDPR

11. Chemical Use on California Strawberries 2002

% of Strawberry Acreage Treated and Total Pounds Active Ingredient (AI) Used

PRODUCT	% BASE ACRES TREATED *	TOTAL POUNDS AI
Insecticides		
Azadirachtin	20.6	248
Bacillus thuringiensis (products combined)	71.4	5,227
Bifenthrin	33.0	1,255
Carbaryl	15.2	9,075
Chlorpyrifos	20.1	5,116
Diazinon	13.0	3,740
Cinnamaldehyde	0.3	445
Dicofol	3.3	1,214
Fenbutatin-oxide	0.1	23
Fenpropathrin	44.3	4,984
Hexythiazox	48.1	2,513
Imidacloprid	15.8	2,102
Malthion	59.2	73,403
Metaldehyde	7.8	2,458
Methomyl	33.9	15,523
Naled	23.9	13,653
Petroleum (products combined)	4.5	107,140
Pyrethrins	6.3	60
Rotenone	2.8	9
Spinosad	60.2	2,762
Herbicides		
Glyphosate	1.4	807
Napropamide	6.2	2,888
Oxyflurofen	0.4	71
Paraquat Dichloride	5.8	1,166
Sethoxydim	0.4	17
Fungicides		
1,3-Dichloropropene	8.9	440,338
Amplelomyces quisqualis	0.5	0
Azoxystrobin	58.1	5,298
Benomyl	10.3	2,103
Captan (products combined)	114.9	222,640
Copper (hydroxide and salts)	13.7	7,754
Cyprodinil	35.2	4,570
Fenhexamid	83.9	30,211
Fludioxonil	35.2	3,046
Fosetyl-al	13.9	14,523
Metlaxyl	0.7	68
Myclobutanil	80.2	5,672
Sulfur	95.3	279,349
Thiophanate-methyl	19.0	4,809
Thiram	55.0	49,224

Data from CDPR

11. Chemical Use on California Strawberries 2002 (continued)

% of Strawberry Acreage Treated and Total Pounds Active Ingredient (AI) Used

PRODUCT	% BASE ACRES TREATED *	TOTAL POUNDS AI
Fumigants		
1,3-Dichloropropene	8.9	440,338
Chloropicrin	81.6	2,910,013
Metam-sodium	4.7	238,030
Methyl Bromide	70.0	3,701,927
Restricted Pesticides for Nursery Use Only		
Chlorothalonil	1.22	536
Insecticides/Aracaracides		
Propargite	0.03	3

Data from CDPR

* Based on 27,300 acres reported in County Agricultural Commissioners' Data, Calendar Year 2002
Note: the acreage figures have been recalculated to correct an inherent error in reporting for strawberries that generally doubles the actual acreage

12. Members of the California Strawberry Work Group

(UC=University of California, UCCE=University of California Cooperative Extension, ARS=Agricultural Research Service of USDA, KAC=Kearney Agricultural Center)

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Note: where provided, the area of interest is included in parentheses (CC=Central Coast, SM=Santa Maria, OX=Oxnard, SC=South Coast, SJV=San Joaquin Valley, SN=Strawberry Nursery)

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