Changes in Integrated Pest Management in Strawberry Production from 2003 to 2021

Emma K. Tribble
Steve Elliott Matt Baur, Ph.D
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Introduction

Pest Management Strategic Plans (PMSPs) help growers develop pest management strategies for specific crops and emphasize the gaps in research, regulations and education that researchers and stakeholders want addressed. Updates to these plans demonstrate advances in pest management, changes to key pests and shifts in priorities for a certain crop.

Photo by California Strawberry Commission.

California produces the vast majority of the nation's strawberries.

In 2002, a work group including strawberry industry members, pest control advisers (PCAs), farm advisors, researchers and representatives from government programs and agencies met to discuss the critical needs in strawberry pest management in California. This group had representation from the California Minor Crops Council, the California Strawberry Commission, the Western Integrated Pest Management Center, the U.S. Department of Agriculture, the U.S. Environmental Protection Agency and Western Region IR-4 Project, which helps develop pesticides for small-acreage specialty crops. The work group released its Pest Management Strategic Plan in 2003. A similar group of stakeholders met in 2016 to create an updated PMSP reflecting the changes in strawberry pest management over the past 13 years. They received input on this new PMSP throughout 2017-2018 and made it available to the public in 2021.

The differences between the 2003 and the 2021 Pest Management Strategic Plans highlight advancements and changes in strawberry pest management.

Key Changes

The 2003 work group was very concerned about finding alternatives to methyl bromide, the main soil fumigant for strawberry fields, due to the Montreal Protocol banning its use. Growers currently use less effective soil fumigants for strawberry production, and diseases that methyl bromide successfully controlled have re-emerged. Much research has been done on alternative soil treatments, disease-resistant cultivars, and other cultural controls to effectively control soilborne diseases, nematodes and weeds.

The 2003 PMSP found that many commonly used insecticides were harsh on beneficials. The use of two of these insecticide classes, organophosphates and carbamates, has decreased by over 60% in strawberry since 2007, as new narrow-spectrum products have been registered. However, these new products have negative effects on pollinators, so California law will limit their use.

Both work groups recognized a need for resistance-management strategies for lygus bugs and spider mites, two major pests of strawberries. While this remains an issue, mechanical controls for lygus bugs and the use of predatory mites for spider mite management have now been widely adopted by growers to suppress these pests non-chemically.

Since 2003, new training and regulations in food safety have been made to protect consumers from food-borne illness.

Strawberry Production

California leads the United States in strawberry production, growing 86% of the nation's fresh strawberries and 98% of its frozen strawberries in 2017. Strawberries are also California's 10th most valuable exported agricultural product, generating over $400 million in 2017. Between 2003 and 2017, strawberry production increased from nearly 30,000 acres to just under 40,000; cultivars released after 2003 have also increased yield per acre. Organic acreage has greatly increased from less than 2% of commercial land in 2003 to 12.6% in 2017.

Strawberries are grown year-round in California; Southern California supplies strawberries in the winter months, and production moves northward as the weather turns warmer. Strawberry plants are first grown in outdoor field nurseries, then transplanted into raised beds with fumigated soil. The strawberries are drip-irrigated and the soil covered with plastic mulch to keep the berries away from the soil and reduce weed growth. Although strawberry is a perennial plant, growers replant with nursery stock annually due to increased pest pressures and reduced yield after a single season.

Methyl Bromide Ban

Strawberry growers use fumigation as the main method for controlling soilborne diseases, nematodes and weeds. In 2003, growers used methyl bromide to fumigate more than 99% of all fields. However, the Montreal Protocol Treaty on Substances that Deplete the Ozone Layer led to the complete phase-out of methyl bromide for preplant

Photo by California Strawberry Commission.

Strawberry growers have reduced organophosphate and carbamate insecticides use by 60% since 2007.

fumigation by 2016. According to the most recent report on the Montreal Protocol, the restrictions on ozone-depleting substances has allowed the ozone layer to begin recovering. If ozone-depleting substances continue to be restricted, scientists predict a full recovery by 2066 (United Nations 2023). To fill the pest management gap left by methyl bromide, growers now fumigate with chloropicrin and 1,3-dichloropropene and occasionally use methyl isothiocyanate (MITC)-generating materials as fumigants for controlling weeds. However, none of these materials control soilborne pests as effectively as methyl bromide did. Macrophomina crown rot and Fusarium wilt, two diseases that were unproblematic when methyl bromide was in use, have caused significant economic damage in recent years.

The University of California, IR-4, the Cal Poly Strawberry Center, the California Strawberry Commission, the USDA Agricultural Research Service (ARS) and individual growers have been actively researching alternatives to methyl bromide since the early 1990s. This research has not led to a change in chemical control methods in California, though new fumigants have been registered in other states. Strawberry growers were already using chloropicrin, MITC-generating materials and 1,3-dichloropropene before the methyl bromide phase-out. Recent research has focused on developing technologies for a more integrated approach to soil pest management, combining new soil treatments with disease-resistant cultivars and cultural controls to create pest management systems applicable to conventional and organic production alike (Bolda et al.).

Alternatives to Fumigation

Two alternative soil treatments developed since 2003, soil solarization and steam treatment, reduce disease and weed populations by raising soil temperature. Soil

solarization involves covering the soil in clear plastic to trap heat produced by sunlight. Solarization is most effective when summer temperatures are consistently warm enough to heat soil to above 122 degrees Fahrenheit, meaning that solarization is impractical for the colder California Central Coast but reasonable for the warmest growing areas (Bolda et al.). For steam treatment, enough steam must be applied to the soil for it to keep a temperature of 160 degrees Fahrenheit for 20 minutes. Traditional sheet steam applications involve covering the soil with a heavy tarp and injecting steam underneath. Researchers are also exploring the effectiveness of mobile steam applicators. Steam treatment can be as effective at controlling weeds and pathogens as the currently available chemical fumigants, but its high cost and slow application process make it infeasible for growers currently (Bolda et al.).

Anaerobic soil disinfestation, a newer soil-treatment technique, affects pests by temporarily removing oxygen from the soil. Growers add a carbon source such as rice bran to the top layer of soil, irrigate to fill the pore space with water and cover the soil with a plastic mulch; microbes consume the oxygen, thus creating anaerobic conditions which are antagonistic to soilborne pathogens. Anaerobic soil disinfestation has been shown to reduce insects, broadleaf annual weeds and Verticillium wilt. Its changes to the soil, such as increasing nitrogen and phosphorus, also increase plant productivity. However, the current method of soil disinfestation does not control Macrophomina crown rot, Fusarium wilt, or perennial weeds (Bolda et al.). In California's Central Coast growing areas specifically, Fusarium wilt increases when growers apply anaerobic soil disinfestation in cooler growing areas. So, while neither anaerobic soil disinfestation nor soil solarization have replaced fumigation, growers have used them to varying degrees.

Photo by Steve Fennimore, UC Davis.

Mobile steamers are being developed as an alternative to fumigation. While effective, they are currently too slow be used commercially.

Growers have also explored tabletop production under high plastic tunnels, a method that eliminates the threat of soilborne pathogens by not using soil. Tabletop production involves growing strawberries using soilless media like peat moss and coconut fiber in troughs suspended above the ground. The height of the troughs also allows workers to pick strawberries in an upright position, improving working conditions and

productivity. Although tabletop systems are common in Europe, they are rare in California due to their high production costs with no significant increase in yield (Bolda et al.). The 2021 PMSP reported that high plastic tunnels with either tabletop or traditional soil systems were only employed on 500 acres in the state.

Crop rotation and planting in fields with no history of disease have also helped mitigate disease and weed risk, particularly in organic systems.

New Cultivars

Since 2003, the University of California, Davis, the University of Florida and private companies have been developing new strawberry cultivars with improved disease-resistance profiles and greater yield per acre. In 2019, UC Davis cultivars accounted for 58.9% of the strawberry acreage grown in California. Between the 2003 and 2021 reports, the main planted UC Davis cultivars shifted from Diamante, Camarosa and Ventana to Monterey, Cabrillo, San Andreas, Portola and Fronteras. All the new cultivars, except Monterey, show better resistance to Verticillium wilt than the older cultivars (California Strawberry Commission). The San Andreas cultivar also has partial field resistance to powdery mildew. UC Davis also bred these cultivars to have higher yields than the cultivars used in 2003. Within the past few years, UC Davis released five new short-day and day-neutral cultivars and two new extreme-day-neutral cultivars, each with equivalent or better disease resistance packages than the cultivars commonly planted (Filmer 2019, Nelson & Marcure 2021). Two of the new UC Davis day-neutral varieties, Moxie and Royal Royce, have yields of up to 29% higher than the common cultivars. These varieties also produce fewer runners, saving more than $5,000 per acre in production costs (Filmer 2019).

Ideally, host-plant resistance works together with other disease-management strategies to significantly reduce disease problems. Diseases can threaten even the most resistant plants if the inoculum levels are high.

Nursery Exemption

Clean nursery stock acts as the primary prevention strategy for nematodes, viruses, phytoplasmas and anthracnose but is essential for all pathogen control. Soilborne pathogens in particular spread easily through contaminated nursery stock and are extremely difficult to eradicate once present in a field. Due to the critical importance of clean nursery stock for successful strawberry production, methyl bromide can still be used to fumigate nursery plants under a Quarantine and Pre-Shipment Exemption. The 2003 Pest Management Strategic Plan work group prioritized obtaining exemptions like this one until suitable alternatives for methyl bromide were found. Although much research has been done, no suitable replacement has been found for nursery fumigation yet, so this exemption is seen as critical by the industry.

Insect Control

Conservation biological control is widely practiced in California strawberries. As a result, there has been movement away from the use of broad-spectrum materials that are known to interfere with biological control

towards narrow spectrum materials that are less likely to affect beneficial species. Between 2007 and 2016, the use of broad-spectrum organophosphates and carbamates decreased by 41.5% and 20.9% respectively in all crops (California Department of Pesticide Regulation Pesticide Registration Branch 2018). One major carbamate, methomyl, is no longer registered for strawberry, reducing all carbamate use in strawberry by 94% during this time period. Organophosphate use on strawberries also decreased by 31% from 2007 to 2016. Unfortunately, some of the new narrow spectrum materials negatively impact pollinators, and, although pollination services are not required for strawberry production, the flowers are attractive and visited by insect pollinators. As a result, new legislation in California will limit the use of some materials known to affect pollinators in the strawberry production system (DPR Pesticide Registration Branch 2018).

Twospotted spider mites, a major strawberry pest in California, have developed resistance to many miticides and chemical and non-chemical alternatives are needed to control these mites and create an effective resistance-management strategy. Since the 2003 report, more products with different modes of action have been registered for strawberry. Although these new pesticides are not widely used, growers can rotate the use of these products with the usual insecticides to delay pesticide resistance. Additionally, micro sprinklers can help suppress spider mites non-chemically by reducing dust levels. This supplemental irrigation system, used primarily during crop establishment, was not common in strawberry production before 2016 but is now used in more than 60% of fields. In the Oxnard area, where dry winds make supplemental irrigation essential during the first few weeks after transplanting, miticide use has deceased 40% since 2015. Compared to the overhead irrigation traditionally used for crop establishment, micro sprinklers can reduce water usage by at least 30% and can lessen the severity of powdery mildew (Dara SK et al. 2016). Companies are advertising the use of micro sprinklers outside of the crop establishment window specifically for spider mite pest management. In addition to dust control, micro sprinklers can lead to increased levels of Phytoseiulus persimilius and other natural spider mite predators in a field; these beneficial insects prefer higher humidity environments (The Toro Company). However, increasing the humidity of the system throughout the growing season can also increase powdery mildew growth.

Photo by Sarah Zukoff, Cal Poly Strawberry Center.

Bees visit strawberry blooms.

More than 80% of growers now use bug vacuums to help control lygus bugs, a pest causing in excess of $100 million in economic losses in the industry annually. This mechanical control has increased as chemical

Photo by California Strawberry Commission.

More than 80% of strawberry growers use vacuums to help control lygus bugs.

pesticides' decreased effectiveness on lygus bugs over time; many growers bought bug vacuums within the past five to 10 years (Nay C 2021). Bug vacuums in 2014 could reduce lygus bug damage in a field by an average of 25% (Thomas HQ et al. 2013). Recently, the Cal Poly Strawberry Center and the California Strawberry Commission released two new bug vacuum models that can remove lygus bugs two to three times as effectively as the conventional model (Wells J et al. 2020). It is not clear how much this will reduce damage in the field, but researchers are expecting lygus bug populations to decrease by one third (Nay C 2021). Unfortunately, bug vacuums can also spread powdery mildew spores in fields with powdery mildew, but researchers have not explored this.

Post-Harvest Human Disease Prevention

All members of the strawberry production and transportation systems must protect strawberries from contamination by micro-organisms that cause human illness, such as E. coli and Salmonella. Poor sanitary conditions during transport, poor worker hygiene and exposure to water or waste can all lead to strawberry contamination. The California Strawberry Commission has been continuously improving its food safety programs regarding the safe transport of strawberries from the field to consumers. The National Science Foundation awarded the commission the prestigious International Food Safety Award in 2010 for its efforts. The California Strawberry Commission also launched a new Food Safety Certificate program in 2012 to teach workers food safety practices related to strawberry harvesting. Congress enacted the Food Safety Modernization Act during the same time period, shifting the focus in the U.S. safety policy for all food products from disease response to disease prevention.

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