Adoption and Impacts of Integrated Pest Management in Agriculture in the Western United States

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Executive Summary

Integrated Pest Management, or IPM, is a scientific approach to pest management that integrates biological, cultural, mechanical and chemical options to control pest problems. The goals of IPM are to reduce risks to people and the environment by using pest biology, environmental information and all available technology to reduce pest damage to acceptable levels by the most economical means.

In 1993, the United States Department of Agriculture and Environmental Protection Agency set a goal that integrated pest management would be practiced on 75% of U.S. crop acreage by the year 2000. A 2001 review that found while some level of IPM had been adopted on about 70% of U.S. crop acreage, chemical pesticide use had increased between 1992 and 2000, and there was only a slight decrease in the amount of the riskiest pesticides used in the same period.

To document IPM adoption and impacts since that review, this report examined peer-reviewed scientific literature and studies conducted by or on behalf of commodity groups or other agriculture interests, published since the year 2000. The data show that many IPM techniques have become so broadly adopted in the West they are now essentially conventional pest management, and that these high levels of IPM adoption are contributing to a reduction in pest-management risks to people and the environment. Western crops and practices are unique, and the findings documented here may not be applicable nationally.

Key Findings

- IPM adoption is widespread in Western agriculture, with many prevention, avoidance, monitoring and selective-suppression practices employed by a large percentage of growers and on a majority of agricultural acreage.

- Pesticide use is declining overall, and in California has declined sharply per dollar of food produced.

- In California, use of many of the most toxic classes of pesticides has declined, although use of carcinogenic pesticides and toxic air contaminant pesticides has increased.

- Pesticide residues are found on food at low concentrations, which are below the legal tolerance limit set by the U.S. Environmental Protection Agency.

Introduction

Integrated Pest Management, or IPM, is a scientific approach to pest management that integrates biological, organic, cultural, mechanical and chemical options to control pest problems. The goal of IPM is to reduce risks to people and the environment by using pest biology, environmental information and all available technology to reduce pest damage to acceptable levels by the most economical means.

In December 1977, the United States Department of Agriculture adopted a policy to develop and encourage the use of IPM. It supported IPM research and demonstration activities, and in 1993 the USDA and U.S. Environmental Protection Agency renewed the federal government's commitment to IPM by setting a goal that integrated pest management would be practiced on 75% of U.S. crop acreage by the year 2000 (U.S. Government Accountability Office, 2001). In 2001, the U.S. Government Accountability Office issued a report on IPM programs that found while the USDA estimated some level of IPM had been adopted on about 70% of U.S. crop acreage, chemical pesticide use had increased between 1992 and 2000, and there was only a slight decrease in the amount of the riskiest pesticides used in the same period (U.S. GAO, 2001).

In the West during that period, IPM was viewed as an expensive and risky pest-management gamble by many growers. A 1996 survey asked Utah tree-fruit growers about the perceived impediments of adopting IPM, and 100% cited higher costs, 98% cited higher risks, and 98% cited lower levels of control (Alston and Reding, 1998). However, as researchers improved and refined IPM techniques and extension services demonstrated and taught IPM practices, attitudes toward IPM changed markedly. Utah tree-fruit growers were resurveyed in 2009 and again asked about the perceived impediments to adopting IPM, and only 23% cited higher costs, 8% cited higher risks and 10% cited lower levels of control. The largest perceived impediment in 2009 was lack of knowledge, cited by 62% of growers (Murray and Alston, 2011).

To document IPM adoption and impacts in the years since the GAO report, this review examined peer-reviewed scientific literature as well as studies conducted by or on behalf of commodity groups or other agriculture interests, published since the year 2000. This review documents both the adoption of IPM in agriculture in the Western United States, and the impact that adoption has had.

The data show that many IPM techniques have become so broadly adopted in the West they are now essentially conventional pest management, and that these high levels of IPM adoption are contributing to a reduction in pest-management risks to people and the environment. This review is not limited to projects funded by the Western IPM Center, but rather is an overview of agricultural IPM in the West generally. Western crops and practices are unique, and the findings documented here may not be applicable nationally.

IPM Practices

The USDA's National Agricultural Statistics Services collects data on IPM pest-management practices and groups those practices into four categories: prevention, avoidance, monitoring and suppression. This report examines the available data from each category in turn.

Prevention

Prevention is the practice of keeping a pest from infesting a field or site. At the state and federal level, prevention includes quarantine and nursery-certification regulations. At the farm level, prevention includes such tactics as using certified pest-free planting material, preventing weeds from reproducing, irrigation scheduling to avoid environmental conditions conducive to disease development, cleaning tillage and harvesting equipment between fields or operations, using field-sanitation procedures, and eliminating alternate hosts or sites for insect pests and disease-causing organisms.

Quarantine is generally a very cost-effective method of pest control since the pest does not contact the host. One way to demonstrate the economic benefits of quarantine is to examine the costs when quarantine efforts fail and a pest is introduced to a new location. This occurred with the introduction of the glassy-winged sharpshooter into California in the late 1990s. The glassy-winged sharpshooter is an effective vector for Pierce's disease of grapes, which was viewed as a minor chronic disease problem in California prior to the introduction of glassy-winged sharpshooters from the Southeast United States. California grape production was valued at $3.2 billion in 2010 and winegrapes accounted for $2.1 billion of that total. Because of the value of the industry, federal, state, local and industry dollars were spent on programs to slow the spread of the glassy-winged sharpshooter and Pierce's disease. The estimated annual cost of these programs is $104.4 million, with $48.3 million funded by various government agencies and the University of California system, and additional costs to the citrus and nursery industries to contain the spread of the glassy-winged sharpshooter. Grape growers bear $56.1 million in costs of lost production and vine replacement. If the program was discontinued and glassy-winged sharpshooters were allowed to become widely spread in California, the costs to grape growers would increase by $185 million (Alston et al., 2014, Tumber et al., 2014). In another example, 25 invasive weeds in agriculture, rangeland, forests and wildlands cost Oregon almost $83.5 million in lost personal income, with two species, Armenian blackberry and Scotch broom, contributing $79.6 million (The Research Group, 2014).

Using certified pest-free planting material is an excellent and economical method of preventing the introduction of pests. Arizona Administrative Code R3-4-233 requires lettuce seed be tested and found free of Lettuce Mosaic Virus in a 30,000 seed sample per seed lot (Arizona Administrative Code). Similarly in Monterey and Imperial counties in California, county ordinances mandate that all seed lots of commercial lettuce be tested and have no Lettuce Mosaic Virus per 30,000 seeds tested (Koike and Davis, 2009; Monterey County Agricultural Commissioner, 2014). The benefits of establishing vineyards with certified Grapevine Leafroll-3 virus-free nursery stock in the North Coast region of California is estimated to be $52.7 million dollars per year (Fuller et al., 2013). Conversely, Potato Virus Y infection of seed potatoes is estimated to cause a 116,000-ton yield loss in Idaho. This translates to a direct loss of $19.5 million a year to the Idaho potato industry, and an indirect loss of an additional $14.6 million a year to the Idaho economy (Aryal, 2013).

The Agricultural Chemical Use Program within USDA's National Agriculture Statistics Service conducts an annual survey of U.S. farmers to collect information on pest management practices, including specific prevention avoidance, monitoring and suppression activities (Figures 1-3 and Appendix). Adoption of specific prevention practices varies from state to state and crop to crop. However, Western farmers report high rates of adoption of crop rotation, tillage of crop residue, cultivation for weed control, management of weeds in field edges, sanitation of equipment between fields, and irrigation management (USDA-NASS, 2014a). Similarly, Western grain storage facility managers report high rates of adoption of sanitation practices in and around the storage facilities (USDA-NASS, 2014a). Detailed prevention-practice adoption rates for specific crops in Western states are available in the Appendix.

In addition to the National Agriculture Statistics Service data, there are numerous studies conducted by researchers and commodity organizations that also show high rates of adoption of prevention practices in Western agriculture.

In Utah, 63% of tree-fruit growers report high-to-moderate use of pruning out diseased wood as a preventative measure (Murray and Alston, 2011). Arizona cotton growers use transgenic Bt cotton, which contains endotoxins of the soil bacterium *Bacillus thuringiensis,* and a pink bollworm eradication program, which has resulted in no insecticide applications for pink bollworm since 2006 (Ellsworth et al., 2012). In Arizona leafy-greens production, growers routinely consider the pest impact of neighboring crops and non-crop areas when preparing to plant new plantings (Palumbo and Castle, 2009). California rice storage facilities use preventative strategies to protect stored rice from pests. Prior to loading with newly harvested rice, 93% thoroughly clean storage facilities, 76.3% treat structures with insecticide, and 66.1% apply insecticide to areas surrounding storage structures (Espino et al., 2014). California cut-flower growers also use several prevention methods to reduce damage from pests. Just over 27% use a pest-free artificial substrate that does not require pre-plant treatment, such as rock wool or coir. Of the rest, prior to planting new beds, 33% use steam treatment, 21% apply compost teas, 15% apply microbial inoculants, 15% use methyl bromide, 8% use 1,3-dichloropropene, 8% use metam sodium, and 5% use soil solarization (Ohmart and Arnold, 2011).

In 2013, Hawaiian nurseries, which ship potted ornamental plants out-of-state, treated 96,000 plants with a value of $4.7 million in an innovative, enclosed hot water shower system to kill quarantine pests. The treatment killed and removed 2,968 coqui frogs and numerous arthropods, slugs, snails and lizards, thus preventing potential rejection of the shipments or distribution of an invasive pest to a new state (Hara, 2014).

Widely Adopted IPM Practices in Western Vegetable Production

		AZ	CA	CO	OR	WA
Prevention	Crop acres cultivated for weed control	+	+	+	+	+
	Equipment and implements cleaned after field work to reduce spread of pests	+	+	+	+	+
	Field edges, ditches, or fence lines were chopped, sprayed, mowed, plowed or burned	+	+	+	+	+
	No-till or minimum till used				+	+
	Plowed down crops residues using conventional tillage	+	+	+	+	+
	Water management practices used	+	+		+	
Avoidance	Crop or plant variety chosen for specific pest resistance	+	+			
	Planting locations planned to avoid cross infestation of pests	+	+			
	Planting or harvest dates adjusted	+				
	Rotated crops during the last 3 years	+	+	+	+	+
Monitoring	Diagnostic laboratory services used for pest detection via soil or plant tissue analysis	+	+	+	+	+
	Scouted - established procedure used	+	+		+	+
	Scouted - for pests due to a pest development model		+	+		+
	Scouted - for pests or beneficial organisms by deliberately going to the crop acres or growing areas	+	+	+	+	+
	Scouted for diseases	+	+	+	+	+
	Scouted for insects and mites	+	+	+	+	+
	Scouted for weeds	+	+	+	+	+
	Weather data used to assist decisions	+	+	+	+	+
	Written or electronic records kept to track the activity of pests	+	+	+	+	+
Suppression	Biological pesticides applied	+				
	Ground covers, mulches, or other physical barriers maintained	+		+	+	+
	Pesticides with different mechanisms of action used to keep pest from becoming resistant to pesticides	+	+	+		+
	Scouting data compared to published information to assist decisions		+			+

Figure 1. Widely adopted pest management prevention, avoidance, monitoring and suppression activities in vegetable production. A "+" denotes a practice adopted on 50% or more of vegetable-production acres in the Western states surveyed as a part of the pest management practices survey. Data reformatted from USDA-NASS survey results in 2011.

Avoidance

Avoidance occurs when pest populations exist in a field but the pest damage can be avoided through cultural practices. Avoidance tactics include rotation to a crop that is not a host for the pest, choosing varieties with genetic resistance to specific pests, choosing varieties with maturity dates that allow harvest before pest populations develop, adjusting planting or harvesting dates to avoid pests, fertilization and irrigation programs to promote good crop development but not promote pests, and not planting in areas where pest populations are likely to cause crop failure. Some prevention and avoidance strategies overlap in some cropping systems.

Based on USDA-NASS pest-management practice surveys, Western farmers report high rates of adoption of crop rotation,

Widely Adopted IPM Practices in Western Fruit and Nut Production

		CA	OR	WA
Prevention	Crop acres cultivated for weed control	+		+
	Crop acres irrigated	+	+	+
	Crop residues removed or burned down	+		
	Equipment and implements cleaned after field work to reduce spread of pests	+	+	+
	Field edges, ditches, or fence lines were chopped, sprayed, mowed, plowed or burned	+	+	+
	Water management practices used	+		+
Monitoring	Diagnostic laboratory services used for pest detection via soil or plant tissue analysis		+	+
	Field mapping data used to assist decisions			+
	Scouted - established procedure used	+	+	+
	Scouted - for pests due to a pest advisory warning		+	+
	Scouted - for pests due to a pest development model		+	+
	Scouted - for pests or beneficial organisms by deliberately going to the crop acres or growing areas	+	+	+
	Scouted for diseases	+	+	+
	Scouted for insects and mites	+	+	+
	Scouted for weeds	+	+	+
	Weather data used to assist decisions	+	+	+
	Written or electronic records kept to track the activity of pests	+	+	+
Suppression	Floral lures, attractants, repellants, pheremone traps, or biological pest control used		+	+
	Ground covers, mulches, or other physical barriers maintained	+	+	+
	Pesticides with different mechanisms of action used to keep pest from becoming resistant to pesticides	+	+	+
	Scouting data compared to published information to assist decisions		+	+

Figure 2. Widely adopted pest management prevention, monitoring and suppression activities in fruit and nut production. A "+" denotes a practice adopted on 50% or more of fruit and nut acres in the Western states surveyed as a part of the pest management practices survey. Data reformatted from USDA-NASS survey results in 2012.

selecting crops or varieties based on specific pest resistance, and adjusting planting or harvesting dates to avoid pest activity (Figures 1-3) (USDA-NASS, 2014a). In California and Oregon nursery and floriculture production, one-third or more of operations report adjusting plant density, growing plants on structures elevated off the ground, and using sterilized growing media to avoid pests (USDA-NASS, 2014a). Detailed avoidance-practice adoption rates for specific crops in Western states are available in the Appendix.

In the Lodi winegrape-growing region of California, more than 50% of growers report using leaf pulling to avoid insect, mite and disease problems on grape clusters (Ohmart, 2008). Leaf pulling involves removing the leaf opposite the grape cluster and one leaf distal and apical from the cluster in order to open the canopy around the grape cluster to reduce relative humidity and increase light penetration. Workers remove the leaves by hand just after fruit set since later removal can cause sunburn of the berries. More

Widely Adopted IPM Practices in Western Winter Wheat Production

		CO	ID	MT	OR	WA
Prevention	Equipment and implements cleaned after field work to reduce spread of pests	+	+	+	+	+
	Field edges, ditches, or fence lines were chopped, sprayed, mowed, plowed or burned		+		+	+
	Field left fallow previous year to manage insects	+				+
	No-till or minimum till used	+	+	+	+	+
	Plowed down crops residues using conventional tillage					+
	Seed treated for insect or disease control after purchase		+	+	+	+
Avoidance	Crop or plant variety chosen for specific pest resistance		+	+	+	+
	Rotated crops during the last 3 years	+	+	+	+	+
Monitoring	Scouted - for pests or beneficial organisms by deliberately going to the crop acres or growing areas	+	+	+	+	+
	Scouted for diseases	+	+	+	+	+
	Scouted for insects and mites	+	+	+	+	+
	Scouted for weeds	+	+	+	+	+
	Weather data used to assist decisions		+	+	+	+
	Written or electronic records kept to track the activity of pests		+		+	+
Suppression	Ground covers, mulches, or other physical barriers maintained	+		+		+

Figure 3. Widely adopted pest management prevention, avoidance, monitoring and suppression activities in winter wheat production. A "+" denotes a practice adopted on 50% or more of winter wheat acres in the Western states surveyed as a part of the pest management practices survey. Data reformatted from USDA-NASS survey results in 2013.

than 50% of growers employ dust reduction practices to avoid conditions conducive to mite damage and use irrigation management to avoid conditions conducive to diseases (Ohmart, 2008).

In Monterey County, California, host-free periods are mandated by county ordinance in order to break pest cycles. The county mandates a lettuce-free period (including endive and escarole) from December 7 to 21 each year in order to break plant-to-plant aphid transmission of Lettuce Mosaic Virus. The county mandates a celery-free period of the month of January each year in order to break aphid transmission of Western Celery Mosaic Virus. Monterey County also mandates that no Lombardy poplar be grown in the Salinas and Pajaro valleys in order to avoid providing an overwintering host for the lettuce root aphid (Monterey County Agricultural Commissioner, 2014).

In Arizona leafy-greens production, growers manage irrigation, fertility and soil salinity to avoid conditions conducive to pest outbreaks (Palumbo and Castle, 2009). In Utah vegetable production, 79% of growers rotate crops and 37% use resistant varieties as pest-avoidance practices (Murray et al., 2011). Similarly in New Mexico, 75% of small-scale growers use crop rotation and 64% use resistant varieties to avoid losses to pests (Grasswitz and Gomez, 2012). In California cut-flower production, 29% use crop rotation and 23% grow perennial flowers to avoid pest losses (Ohmart and Arnold, 2011).

Monitoring

Proper identification of pests and monitoring through scouting programs – including trapping, weather monitoring, disease-forecasting models, degree-day pest-development models and soil testing – are the basis for suppression activities. Records of pest incidence, population and distribution should form the basis for crop rotation, variety selection, economic thresholds and suppressive actions.

Based on USDA-NASS pest management practice surveys, scouting for diseases, insects, mites and weeds is performed on greater than 90% of the acreage for vegetable, fruit and nut crops and greater than 60% of the acreage in potato and small grain crops in all Western states surveyed. In addition, many growers report using laboratory diagnostic services, scouting based on pest-development models or pest advisories, and using weather data to assist in pest-management decision-making (Figures 1-3) (USDA-NASS, 2014a). Detailed monitoring practice adoption rates for specific crops in Western states are available in the Appendix.

The Integrated Pest Management-Pest Information Platform for Education and Extension (ipmPIPE) is a national online system for gathering monitoring and scouting reports for specific pests in soybean, corn, legumes, cucurbits, onions and pecans. The information, along with supporting extension commentary and pest alerts, is available to growers and pest control professionals (VanKirk et al., 2012). Growers in Western states use the legume, onion and pecan ipmPIPEs because those crops are grown in the West, so a portion of the national impact of these programs accrues in the Western

Region. The legume ipmPIPE site had an average of more than 69,000 hits per month through the summer of 2010 (Langham et al., 2011). The onion ipmPIPE site was accessed more than 5,000 times per year. Onion growers, who used pest-monitoring information provided by the online onion ipmPIPE tool, increased yields by 250 pounds per acre and reduced pesticide costs by $390 per acre (Schwartz et al., 2014). The pecan ipmPIPE site was accessed more than 41,000 times per year, which is significant given that the pecan stakeholder community is approximately 5,000 people (Calixto et al., 2011).

Fruit and Nut Crops: In the Milton-Freewater area of Oregon, apple growers have shared codling moth trap counts through an online and email system since 2007. Currently, all 55 apple growers in the area participate in the codling moth areawide mating disruption program. Apple growers in the area reduced total insecticide applications from 22,145 pounds in 2007 to 6,054 pounds in 2010 and that level has been maintained for at least three years. In the same period, maximum in-stream concentrations of chlorpyrifos have been reduced 90% as compared to 2006 levels (Kaiser et al. 2013). This program received the national Search for Excellence-Sustainable Agriculture award from the National Association of County Agricultural Agents in 2014 (www.aces.edu/aacaa/nacaa2014).

An online decision-aid system for the tree-fruit industry developed by Washington State University supports increasingly complex IPM programs for Pacific Northwest tree fruit. The system uses insect and disease models and a network of weather stations to provide information on pest-control decision timing. Pest management professionals who use the decision-aid system provide recommendations for most of the orchards and most of the acres in the state. User surveys estimate the system's value at $73.75 to $75.77 per acre, which translates to a statewide value of $15.8 to $16.3 million per year (Jones et al., 2010). More than 80% of Washington apple growers use degree-day models to predict pest development, routinely monitor for pests, and use pheromone traps for codling moth (Goldberger et al., 2013). Also, most Utah tree-fruit growers scout for pests weekly and some also monitor for beneficial insects (Murray and Alston, 2011).

High percentages of California pear growers use very specific seasonal practices for monitoring pests integrated with pheromone traps, degree-day models with biofix data, and weather data. Figures 4 and 5 illustrate impressive adoption rates for very specific scouting and monitoring practices (SureHarvest, 2013). The also adopt other IPM practices: 91.7% of California pear growers have their orchards scouted by a licensed pest control advisor and they monitor at least twice per year for ground squirrels (83.3%), gophers (79.2%), and voles (70.8%) (SureHarvest, 2013). Most Oregon pear growers (91%) use the services of pest management consultants and meet with them weekly (43%) or every two to three weeks (44%). When asked about changes in monitoring practices from 2008 to 2010, 32.3% increased monitoring for insect pests, 25.8% increased use of pheromone or sticky traps, and 21.4% increased monitoring for natural enemies (Goldberger, 2011a). Similarly, 90% of Washington pear growers use the services of pest management consul-

Dormant-Season Pest Monitoring in California Pear Production

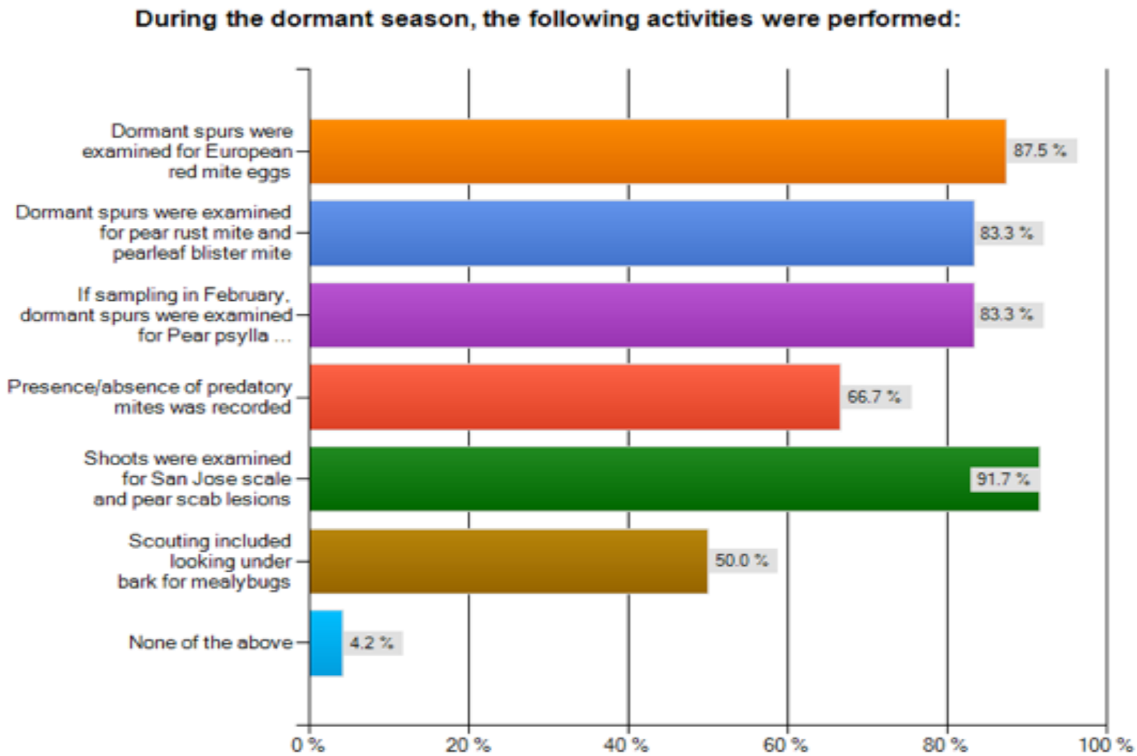


Figure 4. Rates of adoption of specific dormant season pest monitoring activities in California pear production (SureHarvest, 2013).

tants and meet with them weekly (54%) or every two to three weeks (29%). When asked about changes in monitoring practices from 2008 to 2010, 27.5% increased monitoring for insect pests, 22.1% increased use of pheromone or sticky traps, and 17.6% increased monitoring for natural enemies (Goldberger, 2011b).

California almond growers report relying on state-licensed pest control advisors (PCAs) for IPM advice. Almond PCAs use specific monitoring practices for peach twig borer, San Jose scale, mites, navel orangeworms, ants, predatory mites and six-spotted thrips, and incorporate degree-day models into their IPM plans. Almond growers rely on PCAs most heavily for insect management advice, less for disease management advice and least for weed management advice (Brodt et al., 2005). In Oregon, hazelnut (also called filbert) growers scout for filbert aphid, filbert leafroller, obliquebanded leafroller and eastern filbert blight and use pheromone traps for filbertworm (Olsen, 2002). Most California walnut growers (90%) rely on the services of PCAs and meet with them more than once per week (17%), once a week (33%), or every two to three weeks (25%). In addition, 48% of California walnut growers used degree-day calculations to predict codling moth generations in 2009. When asked about changes in pest monitoring practices from 2007 to 2009, 20% increased monitoring for insect pests, 14% increased use of pheromone or sticky traps, and 11% increased monitoring for nat-

Fruit-Harvest Pest Monitoring in California Pear Production

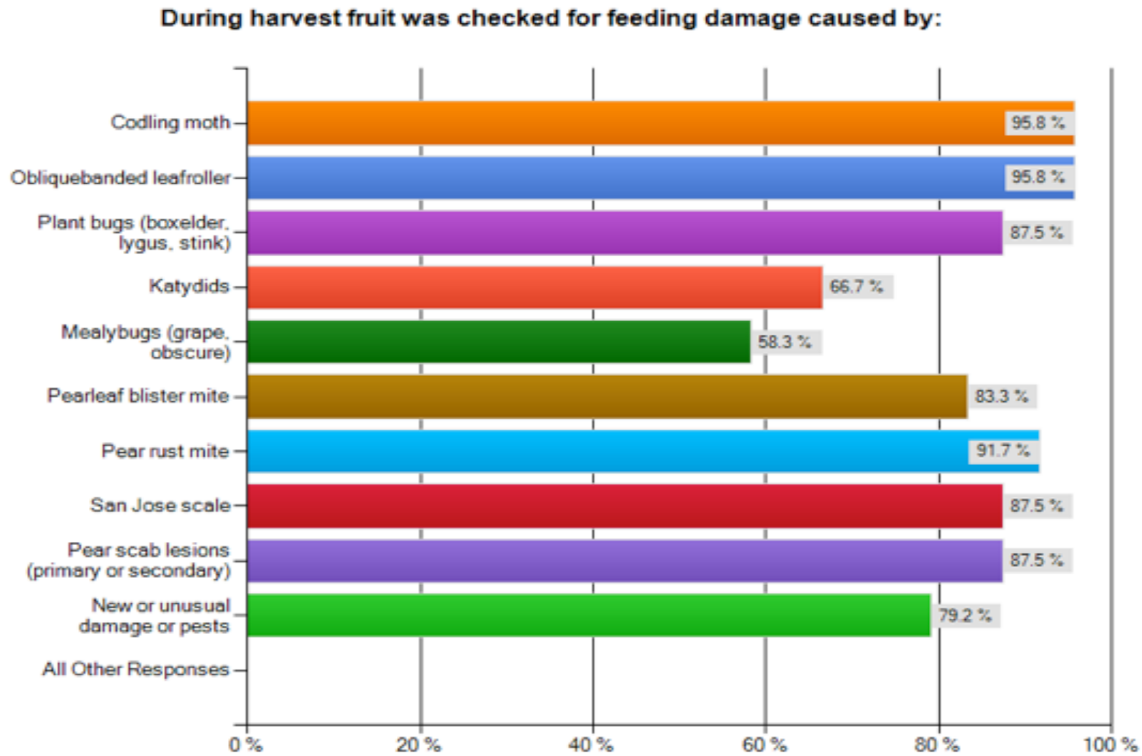


Figure 5. Rates of adoption of specific fruit harvest pest monitoring activities in California pear production (SureHarvest, 2013).

ural enemies (Goldberger, 2010).

In 2013, winegrape growers in one region of Napa Valley formed the Leafroll and Mealybug Alliance to address local spread of Grapevine Leafroll-associated Virus-3 by grape mealybugs. The growers represent 1,900 continuous acres of winegrape vineyards. Growers meet monthly to coordinate mealybug trapping activities, share trap counts, and plan mealybug and leafroll management activities (Arnold et al., 2014). In the Lodi winegrape-growing region of California, more than 50% of growers report monitoring more frequently and more systematically than in previous years. They have also increased monitoring for beneficial insects and used weed monitoring to make herbicide application decisions (Ohmart, 2008).

Adoption of weather-based disease-forecasting models is another method of monitoring. Lybbert et al. (2012) document that growers' responses to disease forecasts are more complex than lengthening or shortening spray intervals based on disease forecasting. Their data combines surveys of California winegrape growers who have and have not adopted the Gubler-Thomas Powdery Mildew Index with pesticide application data from the California Pesticide Use Reporting system. The results suggest that Powdery Mildew Index adopters and non-adopters have similar powdery mildew management strategies at low disease forecast values. At high disease forecast values, adopters are more aggressive in their response than non-adopters: shifting from sulfur to synthetic fungicides, increasing fungicide dosage rates, and tank-mixing multiple fungicides (Lybbert et al., 2012). These are the kinds of changes in powdery mildew management practices recommended by UC IPM guidelines (Gubler et al., 2014).

Agronomic Crops: In Arizona, the cotton IPM program stresses the importance of routine scouting and monitoring for pests and beneficial insects. All commercial cotton acres in Arizona are scouted by state-licensed pest control advisors (Naranjo and Ellsworth 2009; Ellsworth et al., 2012). In California, 88% of cotton growers monitored for Lygus bug, 87% for spider mites and 90% for aphids. Most growers monitor weed populations in their fields but do not keep records or monitor weeds in untreated areas or sample for weed-seed abundance. California cotton growers rely on state-licensed PCAs for pest management and follow their recommendations 88% of the time for insects, 73% of the time for diseases, 70% of the time for weeds, and 61% of the time for nematodes. Cotton growers report that PCAs scout their fields once or twice per week (Brodt et al., 2007).

During California rice storage, 97% of operators monitor rice during storage – usually every one to two weeks – and 81% monitor rice temperature. However, there are also opportunities for improved education since more that 20% of operations that stored rice on-farm did not know the names of the main rice storage insect pests (Espino et al., 2014).

Vegetable Crops: Arizona and Southern California growers produce 95% of the leafy salad greens consumed in the United States in the fall and winter months. State-licensed PCAs scout 100% of lettuce acres at least three to four times per week and growers pay an average of $20 per acre for this service (Palumbo and Castle, 2009). In New Mexico, 94% of small-scale growers regularly monitor for pest damage, 90% check for beneficial insects, 35% use insect-monitoring traps, and 30% keep monitoring records (Grasswitz and Gomez 2012). In Utah, 69% of vegetable growers monitor for pests, 66% base their spray decisions on monitoring, 32% base their spray decisions on thresholds, and 35% identify beneficial insects when monitoring. The Utah survey asked growers to classify themselves as conventional (75%), IPM practitioners (17%) or organic (18%), and asked for adoption rates of 13 specific IPM practices. While self-identified IPM growers used more IPM techniques than the other groups, 65% of the growers used four to seven IPM practices and 23% used eight or more regardless of their self-identification (Murray et al., 2011).

Ornamental Crops: In California cut-flower production, 83% of growers monitor plants at least once per week for pests and 62% use economic thresholds to determine when to apply pesticides (Ohmart and Arnold, 2011).

Suppression

Suppression practices control infestations when pest levels become economically damaging. These practices include applying biological or chemical pesticides, preserving or releasing beneficial organisms that reduce pest populations, and using pheromones to disrupt mating.

In USDA-NASS pest management practice surveys, crop growers in all Western states have moderate to high rates of adoption of using ground covers, mulches or physical barriers to prevent pests, comparing scouting data to published information to assist with decision making, and using pesticides with different modes of action to prevent pests from developing resistance (Figures 1-3) (USDA-NASS, 2014a). Detailed suppression-practice adoption rates for specific crops in Western states are available in the Appendix.

Fruit and Nut Crops: Oregon hazelnut growers implemented filbertworm moth trapping thresholds and shifted from using organophosphates to pyrethroids to control filbertworm, resulting in a reduction of active ingredient insecticides for filbertworm from 88,000 pounds in 1981 to 3,200 pounds in 1997 – a 96% decrease. The filbert aphid parasitoid, *Trioxys pallidus*, was introduced into Oregon in the late 1980s and became well established in hazelnut orchards. This classical biological control allowed hazelnut growers to reduce the amount of pesticide applied for filbert aphid from 15,010 pounds in 1981 to 970 pounds in 1997 – a 93% decrease. Hazelnut growers' adoption of leafroller thresholds reduced the number of insecticide treatments for leafrollers from once every spring to an average of once every four years (Olsen, 2002).

California almond growers were surveyed in 2000 as a follow up to a 1985 pest-management practices survey. By 2000, almond growers had reduced the number of insecticide spray applications throughout the year by implementing an IPM program. Dormant season insecticide sprays declined from 93% to 61% of growers, May sprays declined from 78% to 22%, and hull-split sprays declined from 82% to 59% (Brodt et al., 2005). With the support of a grower-education program (Goodhue et al. 2010), California almond growers significantly reduced dormant season organophosphate applications between 1993 and 2010 (Epstein and Zhang, 2014). California walnut growers consider human health impacts, economic cost and environmental impacts when making pest-management decisions. Specifically, 74.8% ranked human health impacts as a very important factor, 75.6% ranked economic cost as a very important factor, and 60.3% ranked environmental impacts as a very important factor. In their practices, 29.7% reduced their use of insecticides harmful to non-target species from 2007 to 2009, 35.2% increased their use of insecticides that are less harmful to non-target species from 2007 to 2009, and 54% used one or more biological control practice in 2010 (Goldberger, 2010). In stone fruits, California growers reduced organophosphate use primarily by switching to pyrethroids (Epstein and Bassein, 2003).

California pear growers rely on mating disruption to control codling moth and use biologically intensive IPM to control other arthropod pests (Weddle et al., 2009). The transition from organophosphate applications to mating disruption resulted in a savings of $100 to $208 per acre in operational costs (Varela and Elkins, 2008). High percentages of California pear growers report considering environmental effects when selecting pesticides, taking specific steps to reduce pesticide drift, maintaining records of pesticide applications and monitoring performance of pesticide applications (Figures 6 and 7). Also, 91.7% have an orchard-floor vegetation management

Pesticide Data Collected in California Pear Production

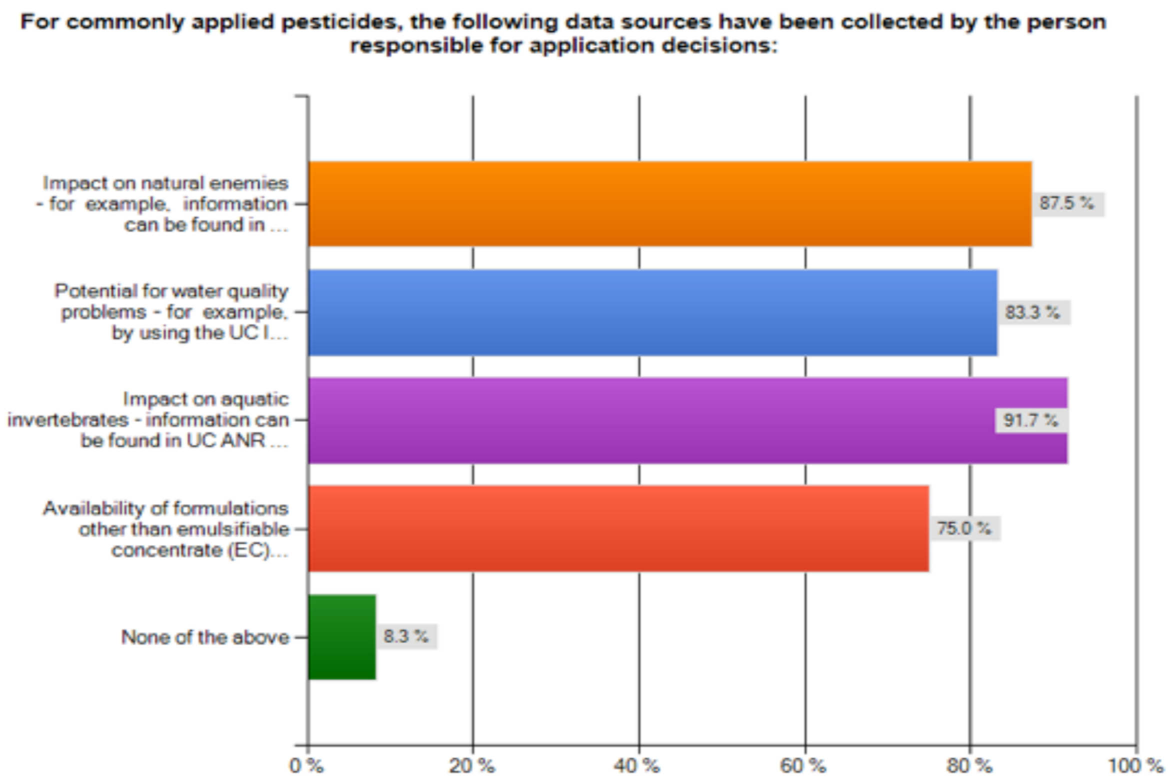


Figure 6. Rates of adoption of specific pesticide information gathering activities in California pear production (SureHarvest, 2013).

program and 73.9% have a written pesticide drift-management plan (SureHarvest, 2013). Oregon pear growers consider human health impacts, economic cost and environmental impacts when making pest management decisions. Specifically, 76.2% ranked human health impacts as a very important factor, 65.4% ranked economic cost as a very important factor, and 62.4% ranked environmental impacts as a very important factor. In their practices, 58.8% reduced their use of insecticides harmful to non-target species from 2008 to 2010, 58.6% increased their use of insecticides that are less harmful to non-target species from 2008 to 2010, and 83% used one or more biological control practice in 2010 (Goldberger, 2011a). Similarly, Washington pear growers consider human health impact, economic cost and environmental impacts when making pest management decisions, with 67.5% ranking human health impacts as a very important factor, 59.9% ranking economic cost as a very important factor and 51.1% ranking environmental impacts as a very important factor. In their practices, 43% reduced their use of insecticides harmful to non-target species from 2008 to 2010, 40.1% increased their use of insecticides that are less harmful to non-target species from 2008 to 2010, and 73% reported using one or more biological control practice in 2010 (Goldberger, 2011b).

In 2006, U.S. EPA began a six year phase-out of the organophosphate insecti-

Pesticide Record Reviews in California Pear Production

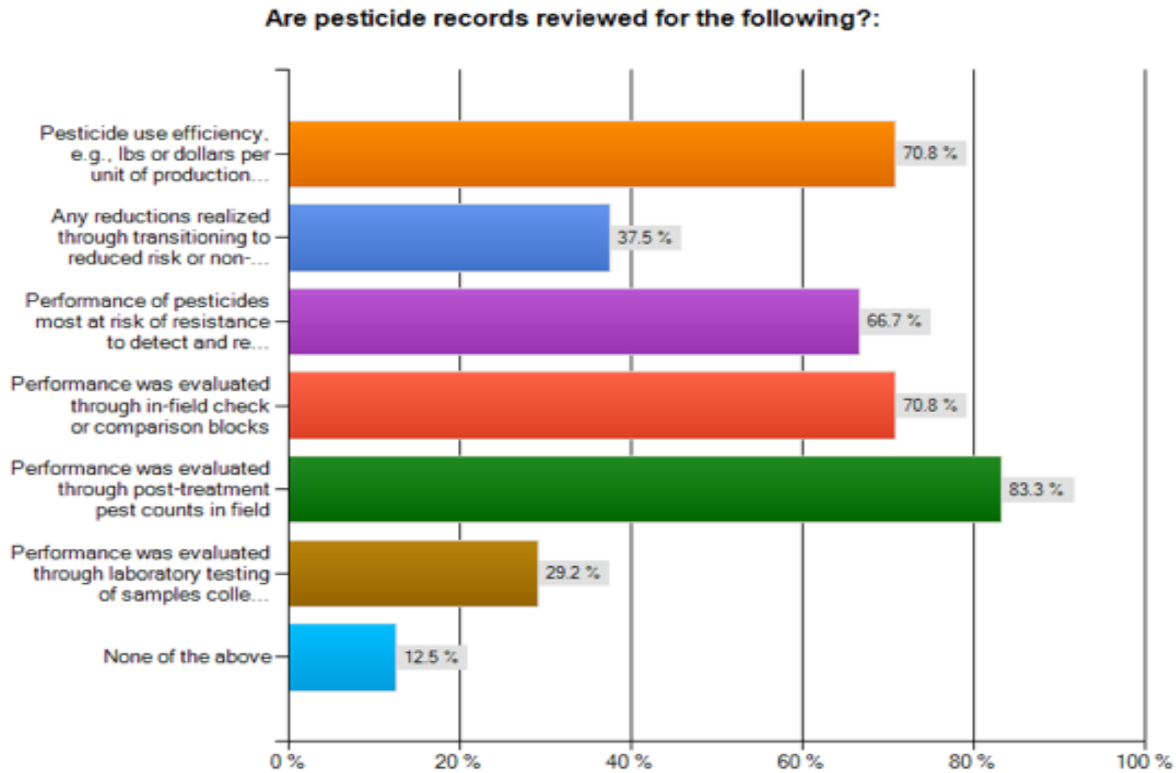


Figure 7. Rates of adoption of specific pesticide record review activities in California pear production (SureHarvest, 2013).

cide azinphos-methyl, which had been the primary pesticide used to control codling moth in apples. In 2009, larger apple growers (measured as acreage and income from apple production) were more likely to have already reduced or eliminated their azinphos-methyl use (Goldberger et al., 2011). Following the six-year phase out of azinphos-methyl, most Washington state apple growers reported a decline in use of all organophosphate insecticides and an increase in the use of lower-risk, non-organophosphate insecticides (Goldberger et al., 2013). Apple growers in Washington and pear growers in Oregon are willing to pay more for pesticides with lower toxicity to insect natural enemies. Based on in-person interviews, apple growers in Washington are willing to pay $26.03 to $26.60 an acre for pesticides with lower toxicity for control of first generation codling moth. Pear growers in Oregon are willing to pay $33.37 to $40.06 an acre for the same feature (Gallardo and Wang, 2013). Utah tree fruit growers report high-to-moderate use of plantings to promote beneficial insects, rotation of pesticide mode of action and sprayer calibration (Murray and Alston, 2011).

California citrus growers vary in their reliance on biological control through natural enemies of cottony cushion scale, California red scale, citrus thrips and citrus red mite. Growers who mostly or entirely rely on natural enemies for pest control varies from 9.9 to 23.1% depending on growing region and specific pest (Grogan and Goodhue, 2012). In Hawaii, 30 growers representing 172 acres cooperate in a three-pronged, areawide fruit fly suppression program. Growers report decreased fruit fly infestation and crop damage (Hara, 2014)

In the Lodi winegrape-growing region of California, more than 50% of growers surveyed use cover crops for natural enemy refuges and use reduced rates of insecticides and miticides. For weed management, more than 50% use reduced rates of herbicides and use contact herbicides but not pre-emergent herbicides. In addition, more than 50% of growers have installed owl nesting boxes for rodent suppression (Ohmart, 2008). In the southern San Joaquin Valley of California, fresh market grape growers implemented IPM practices that resulted in a 42% reduction in organophosphate and carbamate insecticide use from 1999 to 2007. The pesticide use data was obtained from the California Pesticide Use Report database. In California, growers must report all pesticide applications to the California Department of Pesticide Regulation (Bentley, 2009).

Pest-suppression activities rely on good knowledge of pest biology and the correct time to implement suppression tactics. However, with wood-rotting fungi of perennial crops, there is a long delay between infection and disease symptoms. The delay makes adopting disease-control methods many years before seeing symptoms a challenge, but also illustrates the benefits of timely suppression in other crops. Surveys of grapevine trunk-disease management practices in several grape-growing regions in California document that growers typically begin control practices for grapevine trunk diseases several years after the initial infection period. Economic analyses of the costs of delayed pruning, applying pruning wound protectants or double pruning indicates that, if implemented early, these practices increase profits and extend the profitable lifespan of a vineyard (Hillis et al., 2013).

Agronomic Crops: In Arizona cotton production, insect suppression activities include planting transgenic Bt cotton and using whitefly-specific insect growth regulators and Lygus bug feeding inhibitors. To gauge the success of the program, the Arizona Pest Management Center conducts in-depth, annual cotton pest-loss surveys. Cotton pest control advisors quantify the impact of insects and weeds on cotton yields and economic returns, and provide data on insecticide and herbicide use. The data from 1991 to 2011 document significant reductions in the use of broadly toxic insecticides, reductions in the total number of insecticide applications, reductions in foliar insecticide costs per acre, and that no insecticide applications have been needed for pink bollworm since 2006 (Figures 8 and 9) (Naranjo and Ellsworth, 2009; Ellsworth et al., 2012). The Arizona IPM program for whitefly in cotton has reduced foliar-applied insecticides by 70% and generated more than $200 million in control-cost savings and increased yield (Naranjo and Ellsworth, 2009; Ellsworth et al., 2012). In California cotton production, all growers reported using cultivation for weed management, 94% select herbicides based on the weed species identified during monitoring, 73% hand-hoe and 63% hand-pull, rouge or physically remove weeds from fields (Brodt et al., 2007).

In California rice storage facilities, none of the operators treated rice with insecticides as it is put into storage. After rice is in storage, 93% fumigate the rice if insects are found during monitoring (Espino et al. 2014).

Vegetable Crops: The Arizona Pest Management Center conducts in-depth, annual lettuce pest-loss surveys, similar to the cotton surveys described above. Lettuce pest control advisors quantify the impact of insects, weeds and disease on yields and provide data on pesticide use. The data from 1991 to 2011 document significant reductions in the use of broadly toxic insecticides and increases in the use of selective insecticides (Figure 10) (Ellsworth et al., 2012). For example, in the past 10 years the use of older, broadly toxic insecticides (organophosphates, carbamates, endosulfan) has dropped significantly, whereas the use of newer, softer, reduced-risk chemistries (for example, spinetoram, imidacloprid and diamides) has increased (Palumbo 2014). By 2009, selective insecticides were used on more acres of lettuce than broadly toxic insecticides for first time (Palumbo and Castle 2009).

In Utah vegetable production, 37% of growers rotate pesticides as a method of preventing pesticide resistance (Murray et al., 2011). In New Mexico, 65% of small-scale growers grow insectary plants to promote higher populations of the beneficial insects to suppress pest insects (Grasswitz and Gomez, 2012).

Insectide Use Patterns in Arizona Cotton Production

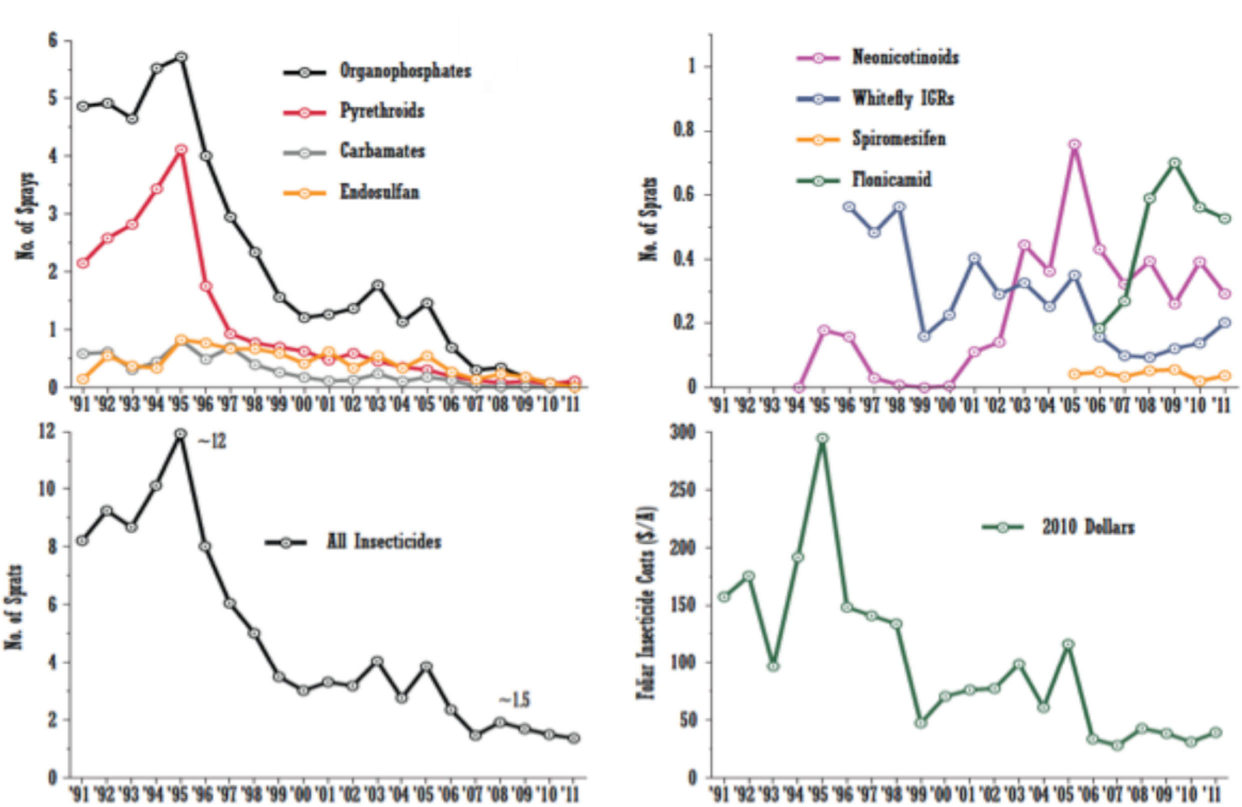
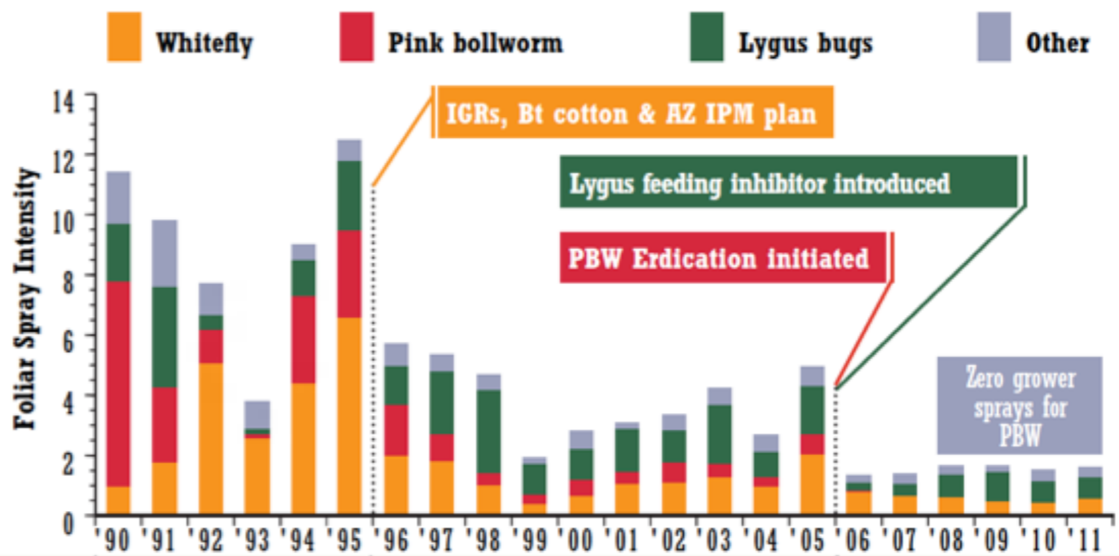


Figure 8. Arizona average cotton insecticide use patterns from 1991 to 2011. Broad spectrum (upper left) and reduced-risk (upper right) insecticide use per acre. All insecticides (lower left) and costs, including applications costs, (lower right) per acre (Ellsworth et al. 2012).

Insectide Use in Arizona Cotton Production, 1990 to 2011



All Insect Sprays	9.0	3.9	1.53
PBW Sprays	2.7	0.64	0.01
Lygus Sprays	1.6	1.5	0.62
Whitefly Sprays	3.6	1.3	0.61

Figure 9. Arizona average cotton insecticide use from 1990 to 2011 by key pest targeted by the application (Ellsworth et al. 2012).

In Hawaiian vegetable production, growers are integrating soil solarization and herbicide application to decrease frequency and volume of herbicides applied (Hara, 2014). Hawaiian crucifier crop growers on the islands of O'ahu and Hawai'i coordinated area-wide insecticide rotations to reduce the risk of diamondback moth developing insecticide resistance (Hara, 2014).

In Oregon, noxious weed suppression using integrated vegetation management decreased the economic impacts of 19 noxious weeds species from $101.5 million in 2000 to $43.1 million in 2014 (The Research Group, 2014).

Ornamental Crops: When California cut-flower producers use pesticides, 76% select least-toxic pesticides for normal pest management, 18% use only Organic Materials Review Institute-approved pesticides, 80% rotate pesticides to prevent pesticide resistance, and 50% use the Resistance Action Committee numbering system as a basis for pesticide rotation. After a pesticide application, 70% use some method to evaluate the effectiveness of pesticide, such as post-treatment pest counts or dollars of pesticide per unit of production (Ohmart and Arnold, 2011).

Impacts of IPM Adoption

A goal of integrated pest management is to reduce the risk pest-management practices pose to human health and the environment. This reduction in risk can be measured in a

Insectide-Use Patterns in Arizona Lettuce Production

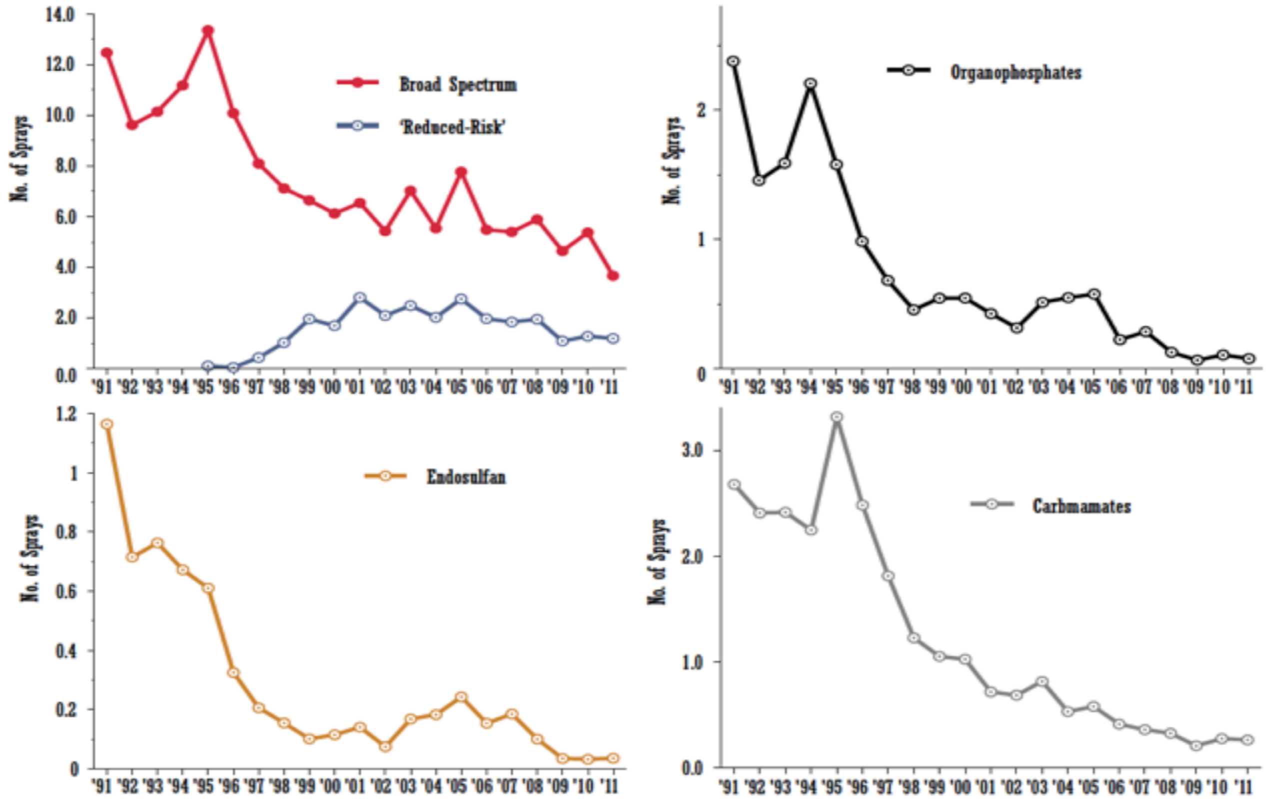


Figure 10. Arizona average lettuce insecticide use patterns per acre from 1991 to 2011. Broad spectrum and reduced risk insecticide applications (upper left). Details of organophosphate (upper right), endosulfan (lower left) and carbamate (lower right) (Ellsworth et al. 2012).

variety of ways – in the total amount of pesticides used, in the amount of the most-toxic categories of pesticides used, in pesticide residues on food, and in pesticide contamination in water supplies. The general trends in all of these categories are decreasing, although use of some of the most-toxic categories of pesticides has increased.

Pesticide Use Data

One barrier to evaluating the effectiveness of integrated pest management programs is the difficultly in accurately measuring pesticide usage. Only California and Arizona require users to report pesticide usage, and the most commonly reported measure of pesticide usage is the total pounds of active ingredient applied – a measurement that does not account for differences in pest specificity, relative toxicity, environmental persistence and the off-site movement potential of the pesticides.

Nationwide pesticide use, measured in pounds of active ingredient applied, has declined from a high in the early 1980s in part due to improved IPM programs for pests in agriculture. In addition, the environmental persistence, rate of application and toxicity of pesticides used has declined in comparison to the 1970s (Fernandez-Cornejo et al., 2014). National-level pesticide-use data is dominated by pesticide use on large acreages of corn and soybeans, which are not widely grown crops in the Western Region. Data for other crops in the national database – rice, cotton, oranges and tomatoes – are not representative of Western pest issues due to differences in climate. For example, cotton grown in Arizona and California has significantly lower insect and disease pressure than the Southeastern United States due to the arid climate of the Southwest.

In California, all agricultural pesticide use is reported to county agricultural commissioners for submission to the California Department of Pesticide Regulation, which releases an annual report of all non-homeowner pesticide use in the state. Total pounds of pesticide active ingredient fluctuates year to year based on weather patterns and shifts in crop production, but has decreased from approximately 191 million pounds in 1995 to about 172 million pounds in 2012 – a 10% decrease (Figure 11) (California Department of Pesticide Regulation, 2014a). However, that decrease occurred while the state's agricultural production increased sharply. California's agricultural gross cash income increased from $22.1 billion on 29.3 million acres in 1995 to $44.7 billion on 25.4 million acres in 2012 – a 102% increase (USDA-NASS, 2014b). For comparison, the cumulative rate of inflation during that period was 40.9% (United States Bureau of Labor Statistics). The average value of agricultural production per acre increased from $754 an acre in 1995 to $1,760 an acre in 2012 (Figure 12). Contributing to the increase in gross cash income were shifts in crops produced from lower-value to higher-value crops, and increases in crop yields. Examples of shifts in crop production were a decrease in cotton acreage from 1,175,800 acres in 1995 to 365,000 acres in 2012 and an increase in pistachio acreage from 60,300 acres in 1995 to 153,000 acres in 2012 (California Depart-

Pounds of Pesticide Active Ingredient Applied in California, 1995-2012

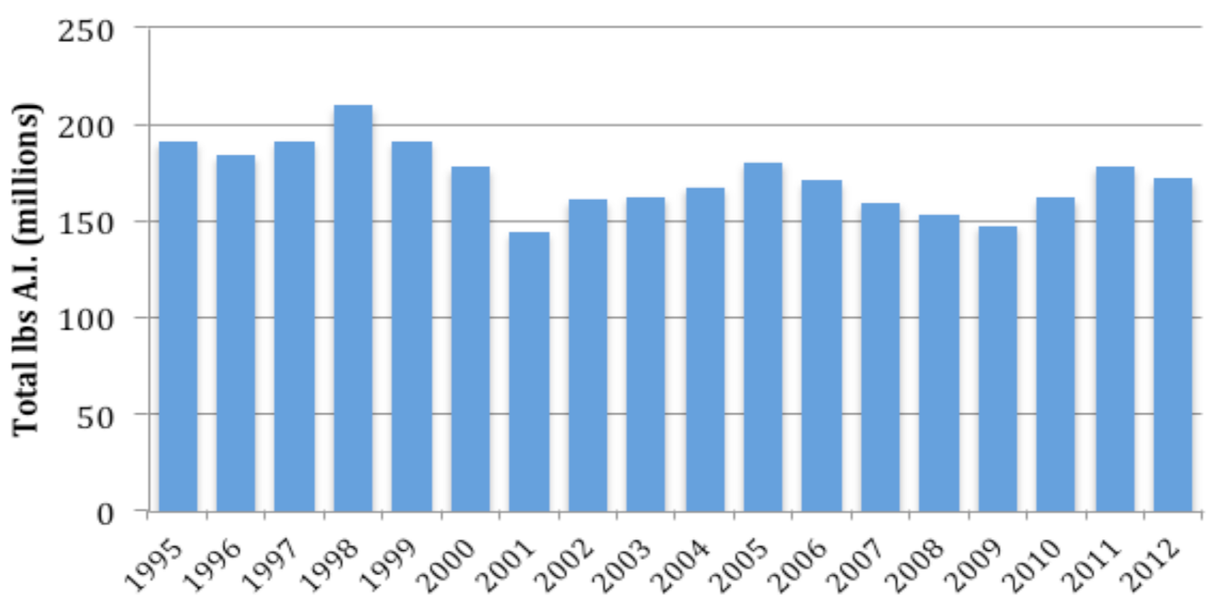


Figure 11. Total pounds of active ingredient applied in agricultural production in California from 1995 to 2012. Data obtained from California Department of Pesticide Regulation (2014a).

Dollar Value of Agricultural Production per Acre in California, 1995-2012

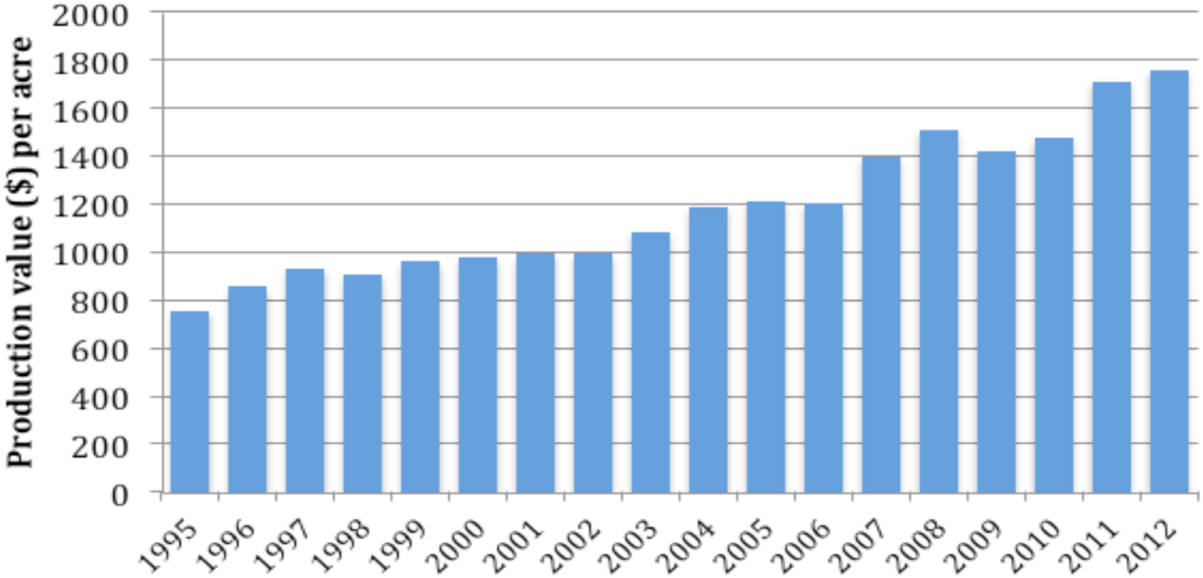


Figure 12. Average California agricultural production value per acre from 1995 to 2012. Total agricultural production value and number of acres in agricultural production obtained from California Agricultural Statistics Review (California Department of Food and Agriculture).

ment of Food and Agriculture). An example of increasing crop yields is the increase in processing tomato yields from an average of 33.4 tons per acre in 1995 to an average of 46.5 tons per acre in 2012 – and yields of over 60 tons per acre were not uncommon in 2012 (Geisseler and Horwath, 2013).

The downward trend in total pounds of pesticide active ingredient applied and the simultaneous upward trends in higher value crops and increasing crop yields has been achieved, in part, by widespread adoption of IPM in California. In 1995, California growers applied 8.6 pounds of pesticide active ingredients for every $1,000 of gross cash income. In 2012, they applied 3.8 pounds per $1,000 – less than half the 1995 rate (Figure 13).

In California, usage trends are also decreasing for some of the most-toxic pesticides, which include pesticides on California's list of chemicals "known to cause reproductive toxicity," cholinesterase-inhibiting pesticides and pesticides designated as having the potential to pollute ground water (California Department of Pesticide Regulation, 2014a). For chemicals known to cause reproductive toxicity, use has declined from nearly 40 million pounds in 1995 to 13.4 million pounds in 2012 – a more than 60% decrease (Figure 14). Use of cholinesterase-inhibiting pesticides has dropped from more than 15 million pounds in 1995 to 4.1 million pounds in 2012, a more than 70% decrease (Figure 15). The use of pesticides designated as having the potential to pollute ground water has declined from more than two million pounds in 1995 to 1.1 million pounds in 2012 – an approximate 50% decrease (Figure 16).

For pesticides identified by the U.S. EPA as B2 carcinogens or on the

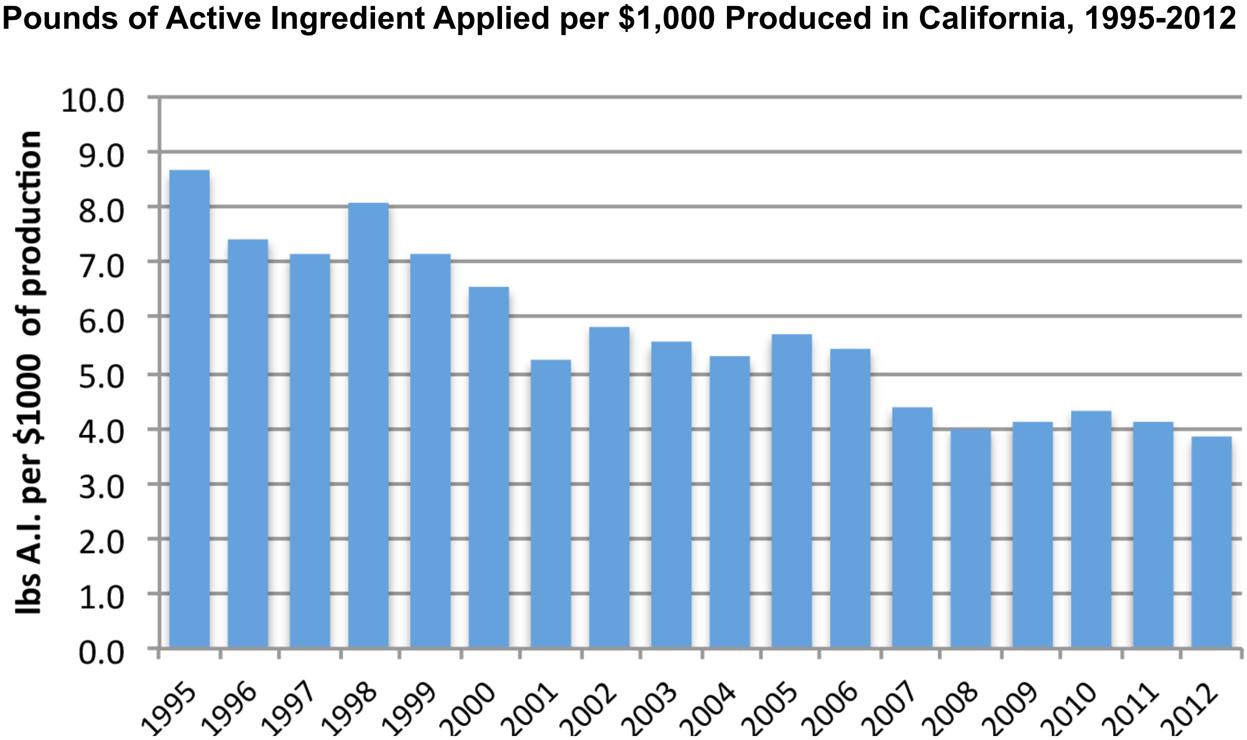


Figure 13. Average pounds of active ingredient applied per $1,000 value of agricultural production from 1995 to 2012. Data obtained from Pesticide Use Annual Summaries (California Department of Pesticide Regulation) and California Agricultural Statistics Review (California Department of Food and Agriculture).

California's Proposition 65 list of chemicals that are "known to cause cancer," use has increased from about 25 million pounds in 1995 to 33.8 million pounds in 2012 – roughly a 35% increase (Figure 17). The California Department of Pesticide Regulation notes that pesticide oils are classified as carcinogens and included in these figures, even though some of those oils may not be carcinogenic due to their high degree of refinement (Figure 18) and oils displace use of other more toxic pesticides (California Department of Pesticide Regulation, 2014a).

The use of toxic air contaminants has displayed some year-to-year variability, but was about 50 million pounds in both 1995 and 2012 (Figure 19) (California Department of Pesticide Regulation, 2014a). The use of fumigants increased from about 39 million pounds in 1995 to 45 million pounds in 2012 - an approximate 15% increase (Figure 20).

Epstein and Zhang (2014) analyzed California pesticide use report data for 49 active ingredients that were used in cumulative state-wide quantities of 22,000 pounds or more in either 1993 or 2000 and appear on at least one of the five toxicity lists: reproductive toxins, carcinogens or probable carcinogens, cholinesterase-inhibiting pesticides, ground water protection program compounds, and toxic air contaminants. Of the 49 active ingredients analyzed between 1993 and 2010, three are no longer in use and 40 have declined in use (Epstein and Zhang, 2014).

In Arizona, many types of agricultural pesticide applications are reported to the

Use of Pesticides Known to Cause Reproductive Toxicity in California, 1995-2012

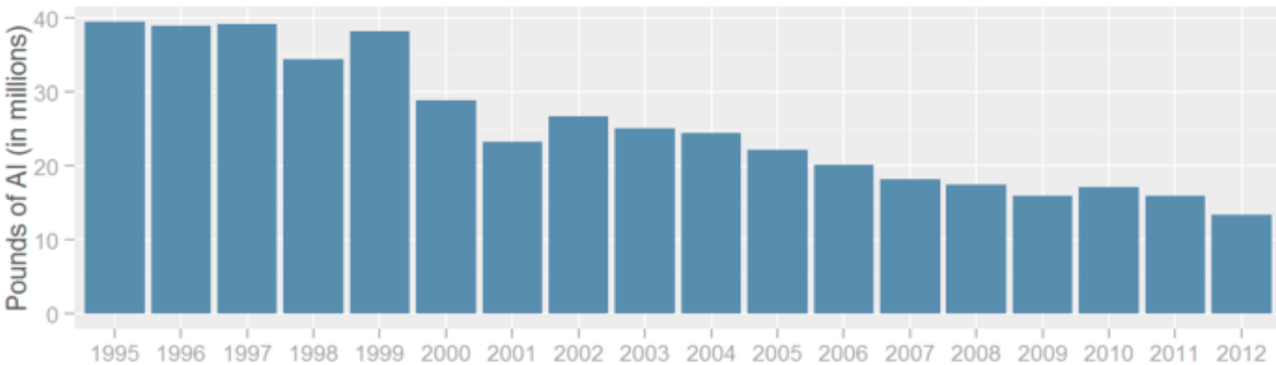


Figure 14. Use trends of pesticides that are on the California's Proposition 65 list of chemicals that are "known to cause reproductive toxicity." Reported pounds of active ingredient (AI) applied include both agricultural and non-agricultural applications (California Department of Pesticide Regulation 2014a).

Use of Cholinesterase-Inhibiting Pesticides in California, 1995-2012

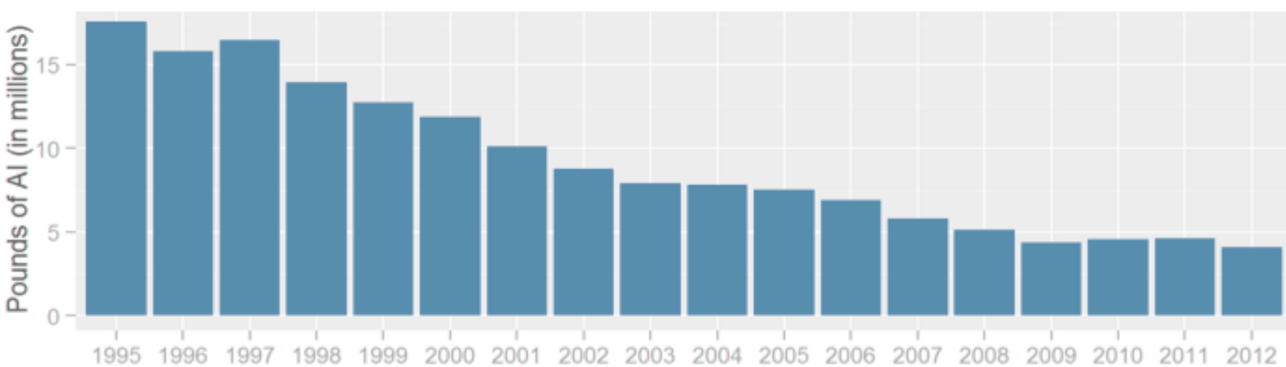


Figure 15. Use trends of pesticides that are cholinesterase-inhibiting pesticides. These pesticides are organophosphate and carbamate active ingredients. Reported pounds of active ingredient (AI) applied include both agricultural and non-agricultural applications (California Department of Pesticide Regulation 2014a).

state, as required by state law. This includes all for-hire applications, all that are applied by air, as stipulated for any products in EPA's Section 18 or 24c exemptions, and all that are listed on Arizona's Department of Environmental Quality's Groundwater Protection List (Arizona Department of Environmental Quality, 2013). Reported data, including crop name, location, product applied, pounds applied, rates and target pest are entered into the state pesticide-use reporting database. The Arizona Pest Management Center of the University of Arizona augments the data with additional information, including EPA product information, pesticide label data, and mode of action tables, and invests significant resources in verifying data and correcting errors. The result is the Arizona Pest Management Center Pesticide Use Database, a historical database from 1991 to the present of Arizona pesticide-use records that is used for research, education, to address pesticide registration questions and needs, and to evaluate the

Use of Groundwater-Polluting Pesticides in California, 1995-2012

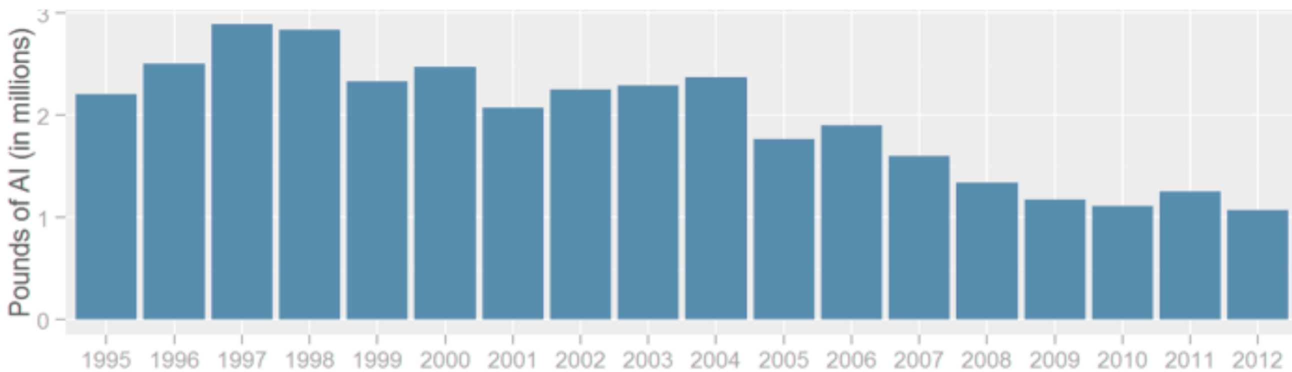


Figure 16. Use trends of pesticides that are the "a" part of DPR's groundwater protection list. These pesticides are the active ingredients listed in the California Code of Regulations. Reported pounds of active ingredient (AI) applied include both agricultural and non-agricultural applications (California Department of Pesticide Regulation 2014a).

Use of Carcenogenic Pesticides in California, 1995-2012

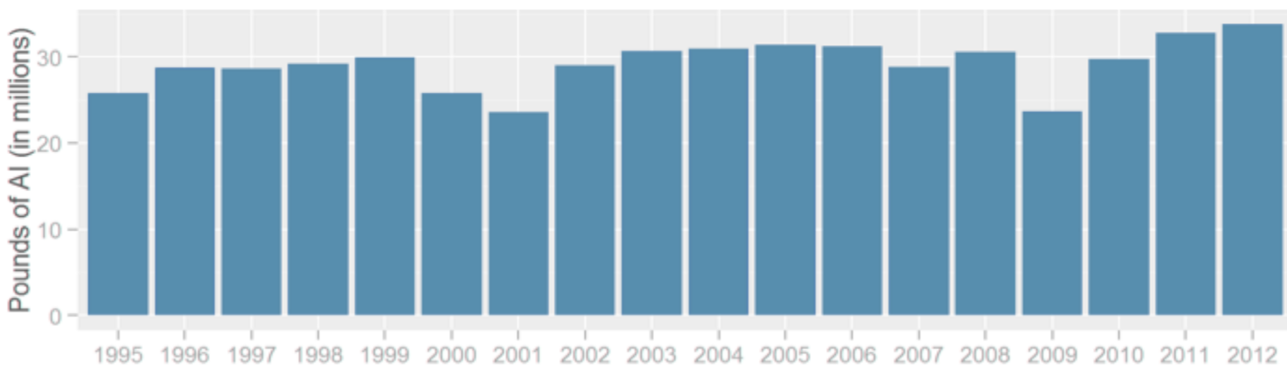


Figure 17. Use trends of pesticides that are listed by U.S. EPA as B2 carcinogens or on the State's Proposition 65 list of chemicals that are "known to cause cancer." Reported pounds of active ingredient (AI) applied include both agricultural and non-agricultural applications (California Department of Pesticide Regulation 2014a).

impact of Arizona IPM programs (United States Government Accountability Office, 2010). While submitted data does not represent 100% of agricultural applications, data are representative of most standard practices with respect to key insect pests (Ellsworth & Palumbo, unpublished data). These data, along with data from Crop Pest Losses surveys described earlier, have documented important impacts of IPM in Arizona crops.

The amount of insecticide active ingredient applied to Arizona cotton has declined by 1.16 million pounds, down 90% compared to 1995 levels. Reductions in control costs and yield losses to arthropods have saved cotton growers more than $388 million since 1996. By 2011, 76% of all cotton insecticides used were selective, meaning they are safer to use and help preserve beneficial insects in the cotton system. Arizona cotton growers have reduced broadly toxic insecticide use by 74% compared to pre-2005 levels (Arizona Pest Management Center, 2014).

The amount of broad-spectrum insecticide applied in Arizona lettuce has declined 72%, from an average of over 10 sprays in 1995 to an average of less than 2.4 sprays in 2011. The use of safer, reduced-risk insecticides in Arizona lettuce has increased 14-fold over the same period. Safety to aquatic and other organisms has been progressively and significantly improved by over 80% from 1991 to 2011, based on a comprehensive spatial analysis of lettuce pesticide use and calculation of pesticide risk scores using the ipmPRiME Pesticide Risk Mitigation Engine

Use of Pesticides that are Oils in California, 1995-2012

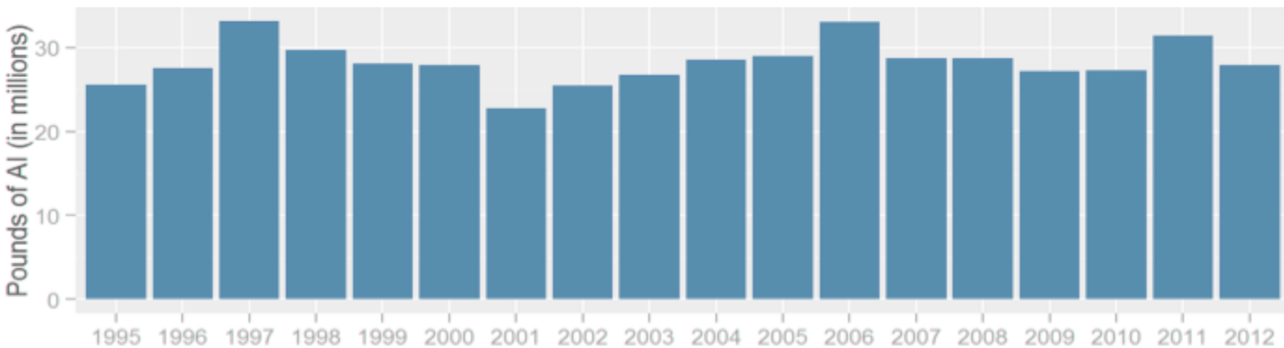


Figure 18. Use trends of pesticides that are oils. As a broad group, oil pesticides and other petroleum distillates are on U.S. EPA's list of B2 carcinogens or the State's Proposition 65 list of chemicals "known to cause cancer." However, these classifications do not distinguish among oil pesticides that may not qualify as carcinogenic due to their degree of refinement. Oils include many different chemicals, but the category used here includes only ones derived from petroleum distillation. Many such oil pesticides also serve as alternatives to high-toxicity chemicals. For this reason, oil pesticide data was classified separately by the California Department of Pesticide Regulation. Reported pounds of active ingredient (AI) applied include both agricultural and non-agricultural applications (California Department of Pesticide Regulation 2014a).

Use of Pesticides that are Toxic Air Contaminents in California, 1995-2012

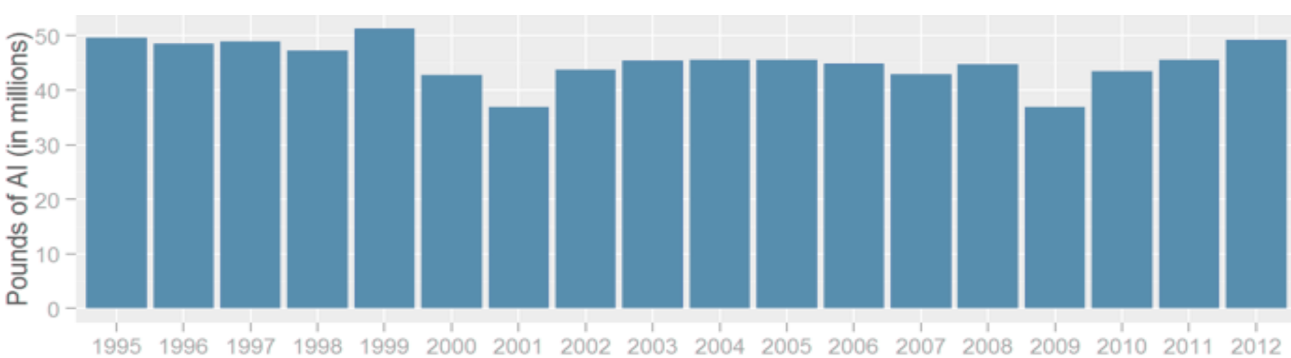


Figure 19. Use trends of pesticides that are on DPR's toxic air contaminants list applied in California. These pesticides are the active ingredients listed in the California Code of Regulations, Title 3, Division 6, Chapter 4, Subchapter 1, Article 1, Section 6860. Reported pounds of active ingredient (AI) applied include both agricultural and non-agricultural applications (California Department of Pesticide Regulation 2014a).

Use of Pesticides that are Fumigants in California, 1995-2012

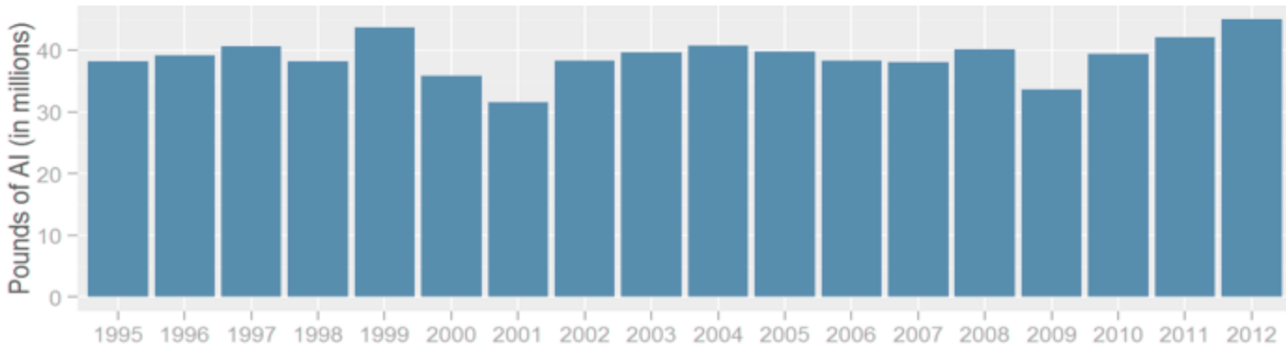


Figure 20. Use trends of pesticides that are fumigants. Reported pounds of active ingredient (AI) applied include both agricultural and non-agricultural applications (California Department of Pesticide Regulation 2014a).

(Arizona Pest Management Center, 2014).

Pesticide Residues on Food

The Pesticide Data Program within the USDA-Agricultural Marketing Service collects fresh and processed food from distribution centers and conducts pesticide residue analysis. The specific commodities change from year to year, and fresh produce samples are washed in running water for 15 to 20 seconds to mimic consumer practices. Samples are then analyzed for over 300 pesticides, metabolites, degradates and isomers in an analysis designed to detect the smallest possible pesticide residues, with limits of detection in parts per billion (USDA-AMS, 2014).

The percentage of samples with pesticide residue exceeding the EPA-established tolerance was 0.5% or less in each of the last 10 years and the majority of samples exceeding pesticide tolerance levels were imported, not domestic. The percentage of samples with residue of a pesticide for which there is no tolerance on that commodity – contamination that may be the result of pesticide drift – was 5.2% or less in each of the last 10 years and the residues were present at very low levels that did not exceed the tolerances established for similar commodities (USDA-AMS, 2014).

The Pesticide Residue Monitoring Program within the California Department of Pesticide Regulation collects raw fruits and vegetables from the channels of trade for pesticide residue analysis. In contrast to the federal Pesticide Data Program, the California program does not change commodities each year and does not include processed food. The Pesticide Residue Monitoring Program analysis methods are continually improved and now detect more than 300 pesticides or breakdown products (California Department of Pesticide Regulation, 2014b).

Most samples have either no detectable residue or pesticide residues within legal tolerances, usually less than 10 percent of the legal tolerance level. The percentage of samples with pesticide residue exceeding the EPA-established tolerance is 1.0% or less in each of the last 10 years. The percentage of samples with residue of a pesticide for which there is no tolerance on that commodity is 4.0% or less in each of the last 10 years, and most of the samples for which there is no tolerance on that commodity have residues in the fractions of parts per million. Data from 2010 to 2013 documents that 97.8% or more of the fruit and vegetables grown in California are in compliance with EPA-established pesticide residue tolerances (California Department of Pesticide Regulation, 2014b).

Pesticide Contamination in Water

The U.S. Geological Survey compared pesticide residues in streams draining agricultural, mixed use and urban areas for the years 2002 to 2011 against the same data for 1992 to 2001 (Stone et al., 2014). Stream classification was based on the dominant land-use in the watershed drained by the stream, and 49 of the 182 streams in the report are in the Western Region. The percentages of assessed streams with at least one pesticide that exceeded aquatic-life benchmarks decreased slightly for agricultural streams, from 69% in 1992 to 2001 to 61% in 2002 to 2011. Mixed-use streams had similar levels of contamination, 45% in 1992-2001 and 46% in 2001-2011, while urban-stream contamination increased sharply from 53% in 1992 to 2001 to 90% in 2002 to 2011 (Stone et al., 2014).

During 1992 to 2001, 17% of agricultural streams and 5% of mixed-use streams had pesticide concentrations that exceeded human-health benchmarks. During 2002 to 2011, human-health benchmarks were exceeded for atrazine in one agricultural stream (Stone et al., 2014). The reduction in agricultural streams with pesticides exceeding aquatic-life and human-health benchmarks is in part due to IPM.

Conclusions

This review of IPM and pest management studies and surveys in the West published since 2000, provides a framework for understanding the adoption and impact of IPM in Western agriculture. The data show that IPM practices are broadly adopted by Western growers. These high rates of adoption have helped contribute to an overall reduction in pesticide use, a marked reduction of pesticides used per dollar of food produced, and reductions in the use of many of the most-toxic categories of pesticides.

The data also show the need to continue to develop and promote effective IPM practices, as full IPM adoption in agriculture is not universal. Growers cite lack of knowledge as a primary barrier to adopting IPM and apply tens of millions of pounds of pesticides on Western crops. IPM has and can continue to develop effective pest-management tools and techniques to protect the West's valuable agriculture industry while protecting human health and the environment.

Appendix

Adoption rates of pest management practices in Western states and crops. Data from USDA-NASS Pest Management Practices Surveys.

Table 1. Adoption rates of pest management practices by percent of acres planted and percent of farming operations for California rice production in 2013. Only practices adopted on 30% or more of acres planted are included in the table. Data obtained from USDA-NASS Pest Management Practices Survey.

PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
PREVENTION: (EQUIPMENT AND IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	47	47
PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	87	89
PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	60	64
PREVENTION: (SEED TREATED FOR INSECT OR DISEASE CONTROL AFTER PURCHASE)	41	46
PREVENTION: (WATER MGMT PRACTICES USED)	36	43
MONITORING: (FIELD MAPPING DATA USED TO ASSIST DECISIONS)	30	33
MONITORING: (SCOUTED - ESTABLISHED PROCESS USED)	38	41
MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	73	76
MONITORING: (SCOUTED FOR DISEASES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	42	36
MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	51	57
MONITORING: (SCOUTED FOR DISEASES)	95	94
MONITORING: (SCOUTED FOR INSECTS & MITES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	41	34
MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	51	57
MONITORING: (SCOUTED FOR INSECTS & MITES)	95	96
MONITORING: (SCOUTED FOR WEEDS - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	41	34
MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	52	56
MONITORING: (SCOUTED FOR WEEDS)	100	100
MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	52	54
MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	35	35
SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	33	37
SUPPRESSION: (SCOUTING DATA COMPARED TO PUBLISHED INFORMATION TO ASSIST DECISIONS)	33	33

Table 2. Adoption rates of pest management practices by percent of acres planted and percent of farming operations for winter wheat production in Western states in 2012. Only practices adopted on 30% or more of acres planted are included in the table. Data obtained from USDA-NASS Pest Management Practices Survey.

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
CO	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	50	49
CO	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	41	48
CO	PREVENTION: (FIELD LEFT FALLOW PREVIOUS YEAR TO MANAGE INSECTS)	53	55
CO	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	72	69
CO	AVOIDANCE: (CROP OR PLANT VARIETY CHOSEN FOR SPECIFIC PEST RESISTANCE)	40	38
CO	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	62	72
CO	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY CONDUCTING GENERAL OBSERVATIONS WHILE PERFORMING ROUTINE TASKS)	39	32
CO	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	57	65
CO	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	94	84
CO	MONITORING: (SCOUTED FOR DISEASES)	75	76
CO	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	93	85
CO	MONITORING: (SCOUTED FOR INSECTS & MITES)	85	84
CO	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	94	87
CO	MONITORING: (SCOUTED FOR WEEDS)	96	97
CO	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	33	28
CO	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	65	69
ID	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	71	61
ID	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	52	66
ID	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	61	50
ID	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	37	54
ID	PREVENTION: (SEED TREATED FOR INSECT OR DISEASE CONTROL AFTER PURCHASE)	63	59
ID	AVOIDANCE: (CROP OR PLANT VARIETY CHOSEN FOR SPECIFIC PEST RESISTANCE)	54	51

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
ID	AVOIDANCE: (PLANTING OR HARVESTING DATES ADJUSTED)	30	32
ID	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	84	93
ID	AVOIDANCE: (ROW SPACING, PLANT DENSITY, OR ROW DIRECTIONS ADJUSTED)	38	32
ID	MONITORING: (FIELD MAPPING DATA USED TO ASSIST DECISIONS)	35	30
ID	MONITORING: (SCOUTED - ESTABLISHED PROCESS USED)	48	40
ID	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	77	71
ID	MONITORING: (SCOUTED FOR DISEASES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	37	27
ID	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	41	59
ID	MONITORING: (SCOUTED FOR DISEASES)	88	86
ID	MONITORING: (SCOUTED FOR INSECTS & MITES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	36	22
ID	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	41	63
ID	MONITORING: (SCOUTED FOR INSECTS & MITES)	76	74
ID	MONITORING: (SCOUTED FOR WEEDS - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	33	22
ID	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	47	65
ID	MONITORING: (SCOUTED FOR WEEDS)	96	94
ID	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	69	69
ID	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	65	55
ID	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	39	36
ID	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	49	49
ID	SUPPRESSION: (SCOUTING DATA COMPARED TO PUBLISHED INFORMATION TO ASSIST DECISIONS)	36	36
MT	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	56	49
MT	PREVENTION: (FIELD LEFT FALLOW PREVIOUS YEAR TO MANAGE INSECTS)	36	41
MT	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	85	75
MT	PREVENTION: (SEED TREATED FOR INSECT OR DISEASE CONTROL AFTER PURCHASE)	91	86
MT	AVOIDANCE: (CROP OR PLANT VARIETY CHOSEN FOR SPECIFIC PEST RESISTANCE)	57	51
MT	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	65	74

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
MT	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	67	67
MT	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	92	96
MT	MONITORING: (SCOUTED FOR DISEASES)	83	87
MT	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	93	96
MT	MONITORING: (SCOUTED FOR INSECTS & MITES)	79	82
MT	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	93	96
MT	MONITORING: (SCOUTED FOR WEEDS)	95	98
MT	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	55	55
MT	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	58	70
OR	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	73	68
OR	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	71	63
OR	PREVENTION: (FIELD LEFT FALLOW PREVIOUS YEAR TO MANAGE INSECTS)	33	16
OR	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	52	45
OR	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	45	56
OR	PREVENTION: (SEED TREATED FOR INSECT OR DISEASE CONTROL AFTER PURCHASE)	64	57
OR	AVOIDANCE: (CROP OR PLANT VARIETY CHOSEN FOR SPECIFIC PEST RESISTANCE)	72	63
OR	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	60	74
OR	AVOIDANCE: (ROW SPACING, PLANT DENSITY, OR ROW DIRECTIONS ADJUSTED)	30	14
OR	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	91	84
OR	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	54	44
OR	MONITORING: (SCOUTED FOR DISEASES)	89	91
OR	MONITORING: (SCOUTED FOR INSECTS & MITES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	30	35
OR	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	56	41
OR	MONITORING: (SCOUTED FOR INSECTS & MITES)	70	80
OR	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	53	44
OR	MONITORING: (SCOUTED FOR WEEDS)	100	100

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
OR	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	90	91
OR	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	52	58
OR	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	49	51
OR	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	47	42
OR	SUPPRESSION: (SCOUTING DATA COMPARED TO PUBLISHED INFORMATION TO ASSIST DECISIONS)	32	41
WA	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	80	76
WA	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	64	64
WA	PREVENTION: (FIELD LEFT FALLOW PREVIOUS YEAR TO MANAGE INSECTS)	50	44
WA	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	67	59
WA	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILL-AGE)	51	52
WA	PREVENTION: (SEED TREATED FOR INSECT OR DISEASE CONTROL AFTER PURCHASE)	53	53
WA	AVOIDANCE: (CROP OR PLANT VARIETY CHOSEN FOR SPECIFIC PEST RESIS-TANCE)	72	73
WA	AVOIDANCE: (PLANTING OR HARVESTING DATES ADJUSTED)	35	41
WA	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	69	69
WA	MONITORING: (FIELD MAPPING DATA USED TO ASSIST DECISIONS)	35	30
WA	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIB-ERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	73	79
WA	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMI-LY MEMBER)	71	67
WA	MONITORING: (SCOUTED FOR DISEASES)	92	94
WA	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	71	59
WA	MONITORING: (SCOUTED FOR INSECTS & MITES)	67	65
WA	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	74	69
WA	MONITORING: (SCOUTED FOR WEEDS)	98	98
WA	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	75	68
WA	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	57	62
WA	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	74	71
WA	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	41	41

Table 3. Adoption rates of pest management practices by percent of acres planted and percent of farming operations for durum and spring wheat production in Montana in 2012. Only practices adopted on 30% or more of acres planted are included in the table. Data obtained from USDA-NASS Pest Management Practices Survey.

COMMODITY	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
WHEAT, DURUM	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	52	50
WHEAT, DURUM	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	62	65
WHEAT, DURUM	PREVENTION: (SEED TREATED FOR INSECT OR DISEASE CONTROL AFTER PURCHASE)	60	57
WHEAT, DURUM	AVOIDANCE: (CROP OR PLANT VARIETY CHOSEN FOR SPECIFIC PEST RESISTANCE)	43	42
WHEAT, DURUM	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	90	90
WHEAT, DURUM	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY CONDUCTING GENERAL OBSERVATIONS WHILE PERFORMING ROUTINE TASKS)	34	27
WHEAT, DURUM	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	64	72
WHEAT, DURUM	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	95	96
WHEAT, DURUM	MONITORING: (SCOUTED FOR DISEASES)	93	92
WHEAT, DURUM	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	99	99
WHEAT, DURUM	MONITORING: (SCOUTED FOR INSECTS & MITES)	87	83
WHEAT, DURUM	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	93	94
WHEAT, DURUM	MONITORING: (SCOUTED FOR WEEDS)	98	99
WHEAT, DURUM	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	65	69
WHEAT, DURUM	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	40	46
WHEAT, DURUM	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	30	38
WHEAT, SPRING	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	62	53
WHEAT, SPRING	PREVENTION: (FIELD LEFT FALLOW PREVIOUS YEAR TO MANAGE INSECTS)	30	35
WHEAT, SPRING	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	79	71
WHEAT, SPRING	PREVENTION: (SEED TREATED FOR INSECT OR DISEASE CONTROL AFTER PURCHASE)	73	73

COMMODITY	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
WHEAT, SPRING	AVOIDANCE: (CROP OR PLANT VARIETY CHOSEN FOR SPECIFIC PEST RESISTANCE)	54	58
WHEAT, SPRING	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	73	71
WHEAT, SPRING	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY CONDUCTING GENERAL OBSERVATIONS WHILE PERFORMING ROUTINE TASKS)	38	41
WHEAT, SPRING	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	58	52
WHEAT, SPRING	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	95	95
WHEAT, SPRING	MONITORING: (SCOUTED FOR DISEASES)	86	80
WHEAT, SPRING	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	95	96
WHEAT, SPRING	MONITORING: (SCOUTED FOR INSECTS & MITES)	79	76
WHEAT, SPRING	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	96	96
WHEAT, SPRING	MONITORING: (SCOUTED FOR WEEDS)	96	94
WHEAT, SPRING	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	60	58
WHEAT, SPRING	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	56	64
WHEAT, SPRING	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	30	28

Table 4. Adoption rates of pest management practices by percent of acres planted and percent of farming operations for fruit and nut production in Western states in 2011. Only practices adopted on 30% or more of acres planted are included in the table. Data obtained from USDA-NASS Pest Management Practices Survey.

STATE	PEST MANAGEMENT PRACTICE	% OF AREA BEARING & NON-BEARING	% OF OPERATIONS
CA	PREVENTION: (CROP ACRES CULTIVATED FOR WEED CONTROL)	65	46
CA	PREVENTION: (CROP ACRES IRRIGATED)	99	93
CA	PREVENTION: (CROP RESIDUES REMOVED OR BURNED DOWN)	52	37
CA	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	72	44
CA	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	73	52
CA	PREVENTION: (WATER MGMT PRACTICES USED)	60	43
CA	MONITORING: (DIAGNOSTIC LABORATORY SERVICES USED FOR PEST DETECTION VIA SOIL OR PLANT TISSUE ANALYSIS)	46	27
CA	MONITORING: (FIELD MAPPING DATA USED TO ASSIST DECISIONS)	38	17
CA	MONITORING: (SCOUTED - ESTABLISHED PROCESS USED)	63	40
CA	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	79	63
CA	MONITORING: (SCOUTED FOR DISEASES - BY EMPLOYEE)	34	13
CA	MONITORING: (SCOUTED FOR DISEASES)	96	86
CA	MONITORING: (SCOUTED FOR INSECTS & MITES - BY EMPLOYEE)	35	13
CA	MONITORING: (SCOUTED FOR INSECTS & MITES)	96	85
CA	MONITORING: (SCOUTED FOR WEEDS - BY EMPLOYEE)	36	15
CA	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	31	62
CA	MONITORING: (SCOUTED FOR WEEDS)	95	86
CA	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	63	41
CA	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	60	36
CA	SUPPRESSION: (FLORAL LURES, ATTRACTANTS, REPELLANTS, PHER-MONE TRAPS, OR BIOLOGICAL PEST CONTROLS USED)	38	25
CA	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	58	44
CA	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	61	36
CA	SUPPRESSION: (SCOUTING DATA COMPARED TO PUBLISHED INFORMA-TION TO ASSIST DECISIONS)	40	25
OR	PREVENTION: (CROP ACRES CULTIVATED FOR WEED CONTROL)	46	33
OR	PREVENTION: (CROP ACRES IRRIGATED)	92	75
OR	PREVENTION: (CROP RESIDUES REMOVED OR BURNED DOWN)	44	48

STATE	PEST MANAGEMENT PRACTICE	% OF AREA BEARING & NON-BEARING	% OF OPERATIONS
OR	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	65	52
OR	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	66	61
OR	PREVENTION: (WATER MGMT PRACTICES USED)	43	26
OR	MONITORING: (DIAGNOSTIC LABORATORY SERVICES USED FOR PEST DETECTION VIA SOIL OR PLANT TISSUE ANALYSIS)	58	25
OR	MONITORING: (FIELD MAPPING DATA USED TO ASSIST DECISIONS)	45	14
OR	MONITORING: (SCOUTED - ESTABLISHED PROCESS USED)	74	40
OR	MONITORING: (SCOUTED - FOR PESTS DUE TO A PEST ADVISORY WARNING)	56	26
OR	MONITORING: (SCOUTED - FOR PESTS DUE TO A PEST DEVELOPMENT MODEL)	58	32
OR	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	85	60
OR	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	42	73
OR	MONITORING: (SCOUTED FOR DISEASES)	97	83
OR	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	41	72
OR	MONITORING: (SCOUTED FOR INSECTS & MITES)	97	84
OR	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	47	78
OR	MONITORING: (SCOUTED FOR WEEDS)	93	79
OR	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	94	68
OR	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	56	30
OR	SUPPRESSION: (BIOLOGICAL PESTICIDES APPLIED)	43	20
OR	SUPPRESSION: (FLORAL LURES, ATTRACTANTS, REPELLANTS, PHERMONE TRAPS, OR BIOLOGICAL PEST CONTROLS USED)	67	40
OR	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	66	43
OR	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	83	41
OR	SUPPRESSION: (SCOUTING DATA COMPARED TO PUBLISHED INFORMATION TO ASSIST DECISIONS)	69	40
WA	PREVENTION: (CROP ACRES CULTIVATED FOR WEED CONTROL)	53	63
WA	PREVENTION: (CROP ACRES IRRIGATED)	99	98
WA	PREVENTION: (CROP RESIDUES REMOVED OR BURNED DOWN)	30	12

STATE	PEST MANAGEMENT PRACTICE	% OF AREA BEARING & NON-BEARING	% OF OPERATIONS
WA	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	74	31
WA	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	89	90
WA	PREVENTION: (WATER MGMT PRACTICES USED)	63	32
WA	MONITORING: (DIAGNOSTIC LABORATORY SERVICES USED FOR PEST DETECTION VIA SOIL OR PLANT TISSUE ANALYSIS)	57	28
WA	MONITORING: (FIELD MAPPING DATA USED TO ASSIST DECISIONS)	65	14
WA	MONITORING: (SCOUTED - ESTABLISHED PROCESS USED)	87	73
WA	MONITORING: (SCOUTED - FOR PESTS DUE TO A PEST ADVISORY WARNING)	57	47
WA	MONITORING: (SCOUTED - FOR PESTS DUE TO A PEST DEVELOPMENT MODEL)	78	24
WA	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	95	80
WA	MONITORING: (SCOUTED FOR DISEASES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	32	12
WA	MONITORING: (SCOUTED FOR DISEASES)	99	97
WA	MONITORING: (SCOUTED FOR INSECTS & MITES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	32	12
WA	MONITORING: (SCOUTED FOR INSECTS & MITES)	99	97
WA	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	41	85
WA	MONITORING: (SCOUTED FOR WEEDS)	98	95
WA	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	94	82
WA	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	76	35
WA	SUPPRESSION: (BIOLOGICAL PESTICIDES APPLIED)	53	59
WA	SUPPRESSION: (FLORAL LURES, ATTRACTANTS, REPELLANTS, PHER-MONE TRAPS, OR BIOLOGICAL PEST CONTROLS USED)	78	69
WA	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	55	77
WA	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	89	75
WA	SUPPRESSION: (SCOUTING DATA COMPARED TO PUBLISHED INFORMA-TION TO ASSIST DECISIONS)	72	38

Table 5. Adoption rates of pest management practices by percent of acres planted and percent of farming operations for barley production in Western states in 2011. Only practices adopted on 30% or more of acres planted are included in the table. Data obtained from USDA-NASS Pest Management Practices Survey.

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
AZ	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	64	63
AZ	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	48	45
AZ	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	61	61
AZ	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	80	81
AZ	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	72	74
AZ	MONITORING: (SCOUTED FOR DISEASES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	37	37
AZ	MONITORING: (SCOUTED FOR DISEASES - BY INDEPENDENT CROP CONSULTANT OR COMMERICAL SCOUT)	38	43
AZ	MONITORING: (SCOUTED FOR DISEASES)	64	67
AZ	MONITORING: (SCOUTED FOR INSECTS & MITES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	33	34
AZ	MONITORING: (SCOUTED FOR INSECTS & MITES - BY INDEPENDENT CROP CONSULTANT OR COMMERICAL SCOUT)	47	48
AZ	MONITORING: (SCOUTED FOR INSECTS & MITES)	75	77
AZ	MONITORING: (SCOUTED FOR WEEDS - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	33	34
AZ	MONITORING: (SCOUTED FOR WEEDS - BY INDEPENDENT CROP CONSULTANT OR COMMERICAL SCOUT)	37	40
AZ	MONITORING: (SCOUTED FOR WEEDS)	84	88
CA	PREVENTION: (EQUIPMENT AND IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	43	51
CA	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	32	33
CA	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	70	56
CA	AVOIDANCE: (CROP OR PLANT VARIETY CHOSEN FOR SPECIFIC PEST RESISTANCE)	44	15
CA	AVOIDANCE: (PLANTING OR HARVESTING DATES ADJUSTED)	38	22
CA	AVOIDANCE: (ROW SPACING, PLANT DENSITY, OR ROW DIRECTIONS ADJUSTED)	30	14
CA	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY CONDUCTING GENERAL OBSERVATIONS WHILE PERFORMING ROUTINE TASKS)	40	34

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
CA	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	42	47
CA	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	67	81
CA	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	67	82
CA	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	90	91
CA	MONITORING: (SCOUTED FOR WEEDS)	82	80
CO	PREVENTION: (EQUIPMENT AND IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	58	43
CO	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	75	78
CO	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	74	78
CO	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	52	53
CO	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	73	84
CO	MONITORING: (DIAGNOSTIC LABORATORY SERVICES USED FOR PEST DETECTION VIA SOIL OR PLANT TISSUE ANALYSIS)	33	35
CO	MONITORING: (SCOUTED - ESTABLISHED PROCESS USED)	42	37
CO	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	81	86
CO	MONITORING: (SCOUTED FOR DISEASES - BY INDEPENDENT CROP CONSULTANT OR COMMERICAL SCOUT)	44	46
CO	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	45	43
CO	MONITORING: (SCOUTED FOR DISEASES)	88	88
CO	MONITORING: (SCOUTED FOR INSECTS & MITES - BY INDEPENDENT CROP CONSULTANT OR COMMERICAL SCOUT)	42	42
CO	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	48	47
CO	MONITORING: (SCOUTED FOR INSECTS & MITES)	91	95
CO	MONITORING: (SCOUTED FOR WEEDS - BY INDEPENDENT CROP CONSULTANT OR COMMERICAL SCOUT)	40	42
CO	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	50	49
CO	MONITORING: (SCOUTED FOR WEEDS)	94	96
CO	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	46	46
CO	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	42	37

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
CO	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	55	52
CO	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	38	43
ID	PREVENTION: (EQUIPMENT AND IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	46	37
ID	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	48	52
ID	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	30	27
ID	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	54	64
ID	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	58	58
ID	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	70	71
ID	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	51	53
ID	MONITORING: (SCOUTED FOR DISEASES)	90	83
ID	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	52	53
ID	MONITORING: (SCOUTED FOR INSECTS & MITES)	88	79
ID	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	58	64
ID	MONITORING: (SCOUTED FOR WEEDS)	98	97
ID	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	67	52
ID	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	37	31
ID	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	44	34
MT	PREVENTION: (EQUIPMENT AND IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	44	30
MT	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	81	67
MT	PREVENTION: (SEED TREATED FOR INSECT OR DISEASE CONTROL AFTER PURCHASE)	75	57
MT	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	67	63
MT	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	66	58
MT	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	90	85
MT	MONITORING: (SCOUTED FOR DISEASES)	78	64

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
MT	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	93	85
MT	MONITORING: (SCOUTED FOR INSECTS & MITES)	70	58
MT	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	94	87
MT	MONITORING: (SCOUTED FOR WEEDS)	92	83
MT	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	65	48
MT	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	51	49
MT	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	34	22
OR	PREVENTION: (EQUIPMENT AND IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	53	42
OR	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	30	31
OR	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	50	53
OR	PREVENTION: (SEED TREATED FOR INSECT OR DISEASE CONTROL AFTER PURCHASE)	33	42
OR	AVOIDANCE: (CROP OR PLANT VARIETY CHOSEN FOR SPECIFIC PEST RESISTANCE)	34	20
OR	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	42	48
OR	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	62	52
OR	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	68	64
OR	MONITORING: (SCOUTED FOR DISEASES)	50	52
OR	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	70	63
OR	MONITORING: (SCOUTED FOR INSECTS & MITES)	36	36
OR	MONITORING: (SCOUTED FOR WEEDS - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	37	29
OR	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	53	65
OR	MONITORING: (SCOUTED FOR WEEDS)	72	69
OR	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	46	54
WA	PREVENTION: (EQUIPMENT AND IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	57	53
WA	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	40	40
WA	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	59	45

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
WA	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	40	49
WA	PREVENTION: (SEED TREATED FOR INSECT OR DISEASE CONTROL AFTER PURCHASE)	37	36
WA	AVOIDANCE: (CROP OR PLANT VARIETY CHOSEN FOR SPECIFIC PEST RESISTANCE)	45	37
WA	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	76	69
WA	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	85	71
WA	MONITORING: (SCOUTED FOR DISEASES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	34	29
WA	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	60	68
WA	MONITORING: (SCOUTED FOR DISEASES)	79	78
WA	MONITORING: (SCOUTED FOR INSECTS & MITES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	34	25
WA	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	63	72
WA	MONITORING: (SCOUTED FOR INSECTS & MITES)	66	64
WA	MONITORING: (SCOUTED FOR WEEDS - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	32	27
WA	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	62	71
WA	MONITORING: (SCOUTED FOR WEEDS)	98	99
WA	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	57	56
WA	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	44	32
WA	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	60	58
WA	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	44	36
WY	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	45	45
WY	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	52	52
WY	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	78	76
WY	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY CONDUCTING GENERAL OBSERVATIONS WHILE PERFORMING ROUTINE TASKS)	30	26
WY	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	61	62
WY	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	87	77

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
WY	MONITORING: (SCOUTED FOR DISEASES)	38	38
WY	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	95	89
WY	MONITORING: (SCOUTED FOR INSECTS & MITES)	48	45
WY	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMI-LY MEMBER)	80	83
WY	MONITORING: (SCOUTED FOR WEEDS)	88	85

Table 6. Adoption rates of pest management practices by percent of acres planted and percent of farming operations for vegetable production in Western states in 2010. Only practices adopted on 30% or more of acres planted are included in the table. Data obtained from USDA-NASS Pest Management Practices Survey.

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
AZ	PREVENTION: (CROP ACRES CULTIVATED FOR WEED CONTROL)	98	96
AZ	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	68	63
AZ	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	95	91
AZ	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	74	78
AZ	PREVENTION: (WATER MGMT PRACTICES USED)	82	72
AZ	AVOIDANCE: (CROP OR PLANT VARIETY CHOSEN FOR SPECIFIC PEST RESISTANCE)	82	54
AZ	AVOIDANCE: (PLANTING LOCATIONS PLANNED TO AVOID CROSS INFESTATION OF PESTS)	77	48
AZ	AVOIDANCE: (PLANTING OR HARVESTING DATES ADJUSTED)	65	41
AZ	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	99	96
AZ	AVOIDANCE: (ROW SPACING, PLANT DENSITY, OR ROW DIRECTIONS ADJUSTED)	31	20
AZ	MONITORING: (DIAGNOSTIC LABORATORY SERVICES USED FOR PEST DETECTION VIA SOIL OR PLANT TISSUE ANALYSIS)	84	62
AZ	MONITORING: (SCOUTED - ESTABLISHED PROCESS USED)	84	65
AZ	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	97	81
AZ	MONITORING: (SCOUTED FOR DISEASES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	46	55
AZ	MONITORING: (SCOUTED FOR DISEASES - BY INDEPENDENT CROP CONSULTANT OR COMMERICAL SCOUT)	38	32
AZ	MONITORING: (SCOUTED FOR DISEASES)	100	94
AZ	MONITORING: (SCOUTED FOR INSECTS & MITES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	46	56
AZ	MONITORING: (SCOUTED FOR INSECTS & MITES - BY INDEPENDENT CROP CONSULTANT OR COMMERICAL SCOUT)	38	31
AZ	MONITORING: (SCOUTED FOR INSECTS & MITES)	100	98
AZ	MONITORING: (SCOUTED FOR WEEDS - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	37	39
AZ	MONITORING: (SCOUTED FOR WEEDS - BY INDEPENDENT CROP CONSULTANT OR COMMERICAL SCOUT)	30	16
AZ	MONITORING: (SCOUTED FOR WEEDS)	98	93
AZ	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	92	71

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
AZ	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	72	68
AZ	SUPPRESSION: (BIOLOGICAL PESTICIDES APPLIED)	64	43
AZ	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRI-ERS MAINTAINED)	81	57
AZ	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	89	59
AZ	SUPPRESSION: (SCOUTING DATA COMPARED TO PUBLISHED INFORMATION TO ASSIST DECISIONS)	41	26
CA	PREVENTION: (CROP ACRES CULTIVATED FOR WEED CONTROL)	69	78
CA	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	74	70
CA	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	85	85
CA	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	72	72
CA	PREVENTION: (WATER MGMT PRACTICES USED)	73	70
CA	AVOIDANCE: (CROP OR PLANT VARIETY CHOSEN FOR SPECIFIC PEST RESIS-TANCE)	50	47
CA	AVOIDANCE: (PLANTING LOCATIONS PLANNED TO AVOID CROSS INFESTA-TION OF PESTS)	57	45
CA	AVOIDANCE: (PLANTING OR HARVESTING DATES ADJUSTED)	34	32
CA	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	76	67
CA	AVOIDANCE: (ROW SPACING, PLANT DENSITY, OR ROW DIRECTIONS AD-JUSTED)	46	41
CA	MONITORING: (DIAGNOSTIC LABORATORY SERVICES USED FOR PEST DE-TECTION VIA SOIL OR PLANT TISSUE ANALYSIS)	63	47
CA	MONITORING: (FIELD MAPPING DATA USED TO ASSIST DECISIONS)	38	37
CA	MONITORING: (SCOUTED - ESTABLISHED PROCESS USED)	81	65
CA	MONITORING: (SCOUTED - FOR PESTS DUE TO A PEST ADVISORY WARN-ING)	35	33
CA	MONITORING: (SCOUTED - FOR PESTS DUE TO A PEST DEVELOPMENT MODEL)	56	38
CA	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	92	82
CA	MONITORING: (SCOUTED FOR DISEASES - BY INDEPENDENT CROP CON-SULTANT OR COMMERICAL SCOUT)	38	32
CA	MONITORING: (SCOUTED FOR DISEASES)	100	96
CA	MONITORING: (SCOUTED FOR INSECTS & MITES - BY INDEPENDENT CROP CONSULTANT OR COMMERICAL SCOUT)	38	31
CA	MONITORING: (SCOUTED FOR INSECTS & MITES)	100	97

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
CA	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	36	50
CA	MONITORING: (SCOUTED FOR WEEDS)	99	95
CA	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	87	68
CA	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	75	55
CA	SUPPRESSION: (BIOLOGICAL PESTICIDES APPLIED)	41	29
CA	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	31	53
CA	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	67	57
CA	SUPPRESSION: (SCOUTING DATA COMPARED TO PUBLISHED INFORMATION TO ASSIST DECISIONS)	57	44
CO	PREVENTION: (CROP ACRES CULTIVATED FOR WEED CONTROL)	100	92
CO	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	50	59
CO	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	92	83
CO	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	50	63
CO	AVOIDANCE: (PLANTING OR HARVESTING DATES ADJUSTED)	44	38
CO	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	57	61
CO	MONITORING: (DIAGNOSTIC LABORATORY SERVICES USED FOR PEST DETECTION VIA SOIL OR PLANT TISSUE ANALYSIS)	52	30
CO	MONITORING: (SCOUTED - ESTABLISHED PROCESS USED)	61	48
CO	MONITORING: (SCOUTED - FOR PESTS DUE TO A PEST ADVISORY WARNING)	36	23
CO	MONITORING: (SCOUTED - FOR PESTS DUE TO A PEST DEVELOPMENT MODEL)	52	27
CO	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	69	58
CO	MONITORING: (SCOUTED FOR DISEASES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	35	19
CO	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	32	59
CO	MONITORING: (SCOUTED FOR DISEASES)	94	85
CO	MONITORING: (SCOUTED FOR INSECTS & MITES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	34	18
CO	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	34	62
CO	MONITORING: (SCOUTED FOR INSECTS & MITES)	97	90

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
CO	MONITORING: (SCOUTED FOR WEEDS - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	34	18
CO	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	34	62
CO	MONITORING: (SCOUTED FOR WEEDS)	97	90
CO	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	59	42
CO	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	62	50
CO	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	56	48
CO	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	61	40
CO	SUPPRESSION: (SCOUTING DATA COMPARED TO PUBLISHED INFORMATION TO ASSIST DECISIONS)	37	25
OR	PREVENTION: (CROP ACRES CULTIVATED FOR WEED CONTROL)	57	73
OR	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	74	58
OR	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	74	73
OR	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	51	24
OR	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	73	66
OR	PREVENTION: (WATER MGMT PRACTICES USED)	53	46
OR	AVOIDANCE: (CROP OR PLANT VARIETY CHOSEN FOR SPECIFIC PEST RESISTANCE)	46	40
OR	AVOIDANCE: (PLANTING LOCATIONS PLANNED TO AVOID CROSS INFESTATION OF PESTS)	42	47
OR	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	80	76
OR	AVOIDANCE: (ROW SPACING, PLANT DENSITY, OR ROW DIRECTIONS ADJUSTED)	38	27
OR	MONITORING: (DIAGNOSTIC LABORATORY SERVICES USED FOR PEST DETECTION VIA SOIL OR PLANT TISSUE ANALYSIS)	50	28
OR	MONITORING: (SCOUTED - ESTABLISHED PROCESS USED)	57	45
OR	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	81	70
OR	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	54	44
OR	MONITORING: (SCOUTED FOR DISEASES)	97	86
OR	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	54	42
OR	MONITORING: (SCOUTED FOR INSECTS & MITES)	99	90

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
OR	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	57	50
OR	MONITORING: (SCOUTED FOR WEEDS)	99	89
OR	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	90	79
OR	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	55	42
OR	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	56	47
OR	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	71	59
OR	SUPPRESSION: (SCOUTING DATA COMPARED TO PUBLISHED INFORMATION TO ASSIST DECISIONS)	39	36
WA	PREVENTION: (CROP ACRES CULTIVATED FOR WEED CONTROL)	90	82
WA	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	91	69
WA	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	91	74
WA	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	53	34
WA	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	72	62
WA	PREVENTION: (WATER MGMT PRACTICES USED)	35	39
WA	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	82	73
WA	MONITORING: (DIAGNOSTIC LABORATORY SERVICES USED FOR PEST DETECTION VIA SOIL OR PLANT TISSUE ANALYSIS)	57	40
WA	MONITORING: (FIELD MAPPING DATA USED TO ASSIST DECISIONS)	36	14
WA	MONITORING: (SCOUTED - ESTABLISHED PROCESS USED)	83	52
WA	MONITORING: (SCOUTED - FOR PESTS DUE TO A PEST ADVISORY WARNING)	47	23
WA	MONITORING: (SCOUTED - FOR PESTS DUE TO A PEST DEVELOPMENT MODEL)	59	28
WA	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	98	73
WA	MONITORING: (SCOUTED FOR DISEASES - BY EMPLOYEE)	38	12
WA	MONITORING: (SCOUTED FOR DISEASES)	99	96
WA	MONITORING: (SCOUTED FOR INSECTS & MITES - BY EMPLOYEE)	37	12
WA	MONITORING: (SCOUTED FOR INSECTS & MITES)	100	98
WA	MONITORING: (SCOUTED FOR WEEDS - BY EMPLOYEE)	38	12
WA	MONITORING: (SCOUTED FOR WEEDS)	100	97
WA	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	91	59
WA	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	89	51

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
WA	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	60	54
WA	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	51	40
WA	SUPPRESSION: (SCOUTING DATA COMPARED TO PUBLISHED INFORMATION TO ASSIST DECISIONS)	50	30

Table 7. Adoption rates of pest management practices by percent of acres planted and percent of farming operations for fall potato production in Western states in 2009. Only practices adopted on 30% or more of acres planted are included in the table. Data obtained from USDA-NASS Pest Management Practices Survey.

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
CO	PREVENTION: (BENEFICIAL INSECT OR VERTEBRATE HABITAT MAINTAINED)	59	52
CO	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	100	100
CO	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	85	89
CO	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	60	57
CO	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	69	70
CO	PREVENTION: (SEED TREATED FOR INSECT OR DISEASE CONTROL AFTER PURCHASE)	88	88
CO	PREVENTION: (WATER MGMT PRACTICES USED)	94	91
CO	AVOIDANCE: (CROP OR PLANT VARIETY CHOSEN FOR SPECIFIC PEST RESISTANCE)	66	62
CO	AVOIDANCE: (PLANTING LOCATIONS PLANNED TO AVOID CROSS INFESTATION OF PESTS)	47	40
CO	AVOIDANCE: (PLANTING OR HARVESTING DATES ADJUSTED)	78	77
CO	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	91	89
CO	AVOIDANCE: (ROW SPACING, PLANT DENSITY, OR ROW DIRECTIONS ADJUSTED)	51	46
CO	MONITORING: (DIAGNOSTIC LABORATORY SERVICES USED FOR PEST DETECTION VIA SOIL OR PLANT TISSUE ANALYSIS)	97	94
CO	MONITORING: (FIELD MAPPING DATA USED TO ASSIST DECISIONS)	43	39
CO	MONITORING: (SCOUTED - ESTABLISHED PROCESS USED)	61	57
CO	MONITORING: (SCOUTED - FOR PESTS DUE TO A PEST DEVELOPMENT MODEL)	45	38
CO	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	87	90
CO	MONITORING: (SCOUTED FOR DISEASES - BY INDEPENDENT CROP CONSULTANT OR COMMERICAL SCOUT)	59	60
CO	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	41	40
CO	MONITORING: (SCOUTED FOR DISEASES)	89	87
CO	MONITORING: (SCOUTED FOR INSECTS & MITES - BY INDEPENDENT CROP CONSULTANT OR COMMERICAL SCOUT)	59	60
CO	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	41	40
CO	MONITORING: (SCOUTED FOR INSECTS & MITES)	89	87

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
CO	MONITORING: (SCOUTED FOR WEEDS - BY INDEPENDENT CROP CONSULTANT OR COMMERICAL SCOUT)	59	60
CO	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	41	40
CO	MONITORING: (SCOUTED FOR WEEDS)	89	87
CO	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	76	67
CO	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	84	82
CO	SUPPRESSION: (BUFFER STRIPS OR BORDER ROWS MAINTAINED TO ISOLATE ORGANIC FROM NON ORGANIC CROPS)	41	35
CO	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	52	51
CO	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	58	52
CO	SUPPRESSION: (SCOUTING DATA COMPARED TO PUBLISHED INFORMATION TO ASSIST DECISIONS)	35	33
ID	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	83	83
ID	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	75	73
ID	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	62	64
ID	PREVENTION: (SEED TREATED FOR INSECT OR DISEASE CONTROL AFTER PURCHASE)	82	83
ID	PREVENTION: (WATER MGMT PRACTICES USED)	59	58
ID	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	87	91
ID	MONITORING: (DIAGNOSTIC LABORATORY SERVICES USED FOR PEST DETECTION VIA SOIL OR PLANT TISSUE ANALYSIS)	48	46
ID	MONITORING: (FIELD MAPPING DATA USED TO ASSIST DECISIONS)	37	39
ID	MONITORING: (SCOUTED - ESTABLISHED PROCESS USED)	41	43
ID	MONITORING: (SCOUTED - FOR PESTS DUE TO A PEST DEVELOPMENT MODEL)	30	27
ID	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	81	77
ID	MONITORING: (SCOUTED FOR DISEASES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	47	49
ID	MONITORING: (SCOUTED FOR DISEASES)	98	98
ID	MONITORING: (SCOUTED FOR INSECTS & MITES - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	45	48
ID	MONITORING: (SCOUTED FOR INSECTS & MITES)	98	98

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
ID	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	50	51
ID	MONITORING: (SCOUTED FOR WEEDS)	99	99
ID	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	72	72
ID	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	51	51
ID	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	65	66
ID	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	65	65
ID	SUPPRESSION: (SCOUTING DATA COMPARED TO PUBLISHED INFORMATION TO ASSIST DECISIONS)	39	36
WA	PREVENTION: (EQUIPMENT & IMPLEMENTS CLEANED AFTER FIELD WORK TO REDUCE SPREAD OF PESTS)	82	69
WA	PREVENTION: (FIELD EDGES, DITCHES, OR FENCE LINES WERE CHOPPED, SPRAYED, MOWED, PLOWED, OR BURNED)	80	83
WA	PREVENTION: (NO-TILL OR MINIMUM TILL USED)	35	27
WA	PREVENTION: (PLOWED DOWN CROP RESIDUE USING CONVENTIONAL TILLAGE)	75	77
WA	PREVENTION: (SEED TREATED FOR INSECT OR DISEASE CONTROL AFTER PURCHASE)	83	68
WA	PREVENTION: (WATER MGMT PRACTICES USED)	46	43
WA	AVOIDANCE: (PLANTING LOCATIONS PLANNED TO AVOID CROSS INFESTATION OF PESTS)	48	40
WA	AVOIDANCE: (ROTATED CROPS DURING PAST 3 YEARS)	95	95
WA	MONITORING: (DIAGNOSTIC LABORATORY SERVICES USED FOR PEST DETECTION VIA SOIL OR PLANT TISSUE ANALYSIS)	76	64
WA	MONITORING: (FIELD MAPPING DATA USED TO ASSIST DECISIONS)	40	33
WA	MONITORING: (SCOUTED - ESTABLISHED PROCESS USED)	69	66
WA	MONITORING: (SCOUTED - FOR PESTS DUE TO A PEST ADVISORY WARNING)	71	57
WA	MONITORING: (SCOUTED - FOR PESTS DUE TO A PEST DEVELOPMENT MODEL)	42	39
WA	MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	99	91
WA	MONITORING: (SCOUTED FOR DISEASES - BY EMPLOYEE)	31	29
WA	MONITORING: (SCOUTED FOR DISEASES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	36	30
WA	MONITORING: (SCOUTED FOR DISEASES)	100	99
WA	MONITORING: (SCOUTED FOR INSECTS & MITES - BY EMPLOYEE)	31	29

STATE	PEST MANAGEMENT PRACTICE	% OF AREA PLANTED	% OF OPERATIONS
WA	MONITORING: (SCOUTED FOR INSECTS & MITES - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	37	31
WA	MONITORING: (SCOUTED FOR INSECTS & MITES)	100	99
WA	MONITORING: (SCOUTED FOR WEEDS - BY EMPLOYEE)	32	30
WA	MONITORING: (SCOUTED FOR WEEDS - BY FARM SUPPLY COMPANY OR CHEMICAL DEALER)	35	29
WA	MONITORING: (SCOUTED FOR WEEDS - BY OPERATOR, PARTNER, OR FAMILY MEMBER)	30	37
WA	MONITORING: (SCOUTED FOR WEEDS)	98	98
WA	MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	93	86
WA	MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	83	71
WA	SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	47	49
WA	SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	93	84
WA	SUPPRESSION: (SCOUTING DATA COMPARED TO PUBLISHED INFORMATION TO ASSIST DECISIONS)	37	36

Table 8. Adoption rates of pest management practices by percent of operations for stored grain in Western states in 2009. Only practices adopted by 30% or more of operations in at least one state are included in the table. Data obtained from USDA-NASS Pest Management Practices Survey.

		% OF OPERATIONS				
PERIOD	**PEST MANAGEMENT PRACTICE**	**CO**	**ID**	**MT**	**OR**	**WA**
MARKETING YEAR	CLEANING ACTIVITIES: (CLEAN AERATION DUCTS)	54	77	39	74	80
MARKETING YEAR	CLEANING ACTIVITIES: (CONTROL VEGETATION AROUND STORAGE)	82	94	99	88	92
MARKETING YEAR	CLEANING ACTIVITIES: (CORE BINS AFTER FILLING)	57	58	50	40	63
MARKETING YEAR	CLEANING ACTIVITIES: (FUMIGATE EMPTY STORAGE)	37	12	18	21	27
MARKETING YEAR	CLEANING ACTIVITIES: (PICK UP SPILLED CROP)	84	99	93	86	96
MARKETING YEAR	CLEANING ACTIVITIES: (SWEEP OR VACUUM EMPTY STORAGE)	77	93	88	91	98
MARKETING YEAR	FUMIGATION SCHEDULE: (BASED ON STORAGE SAMPLES)	41	43	19	42	18
MARKETING YEAR	FUMIGATION SCHEDULE: (BASED ON VISUAL INSPECTION)	50	30	62	52	44
MARKETING YEAR	MECHANICAL DEVICES: (AERATION CONTROLLER)	40	71	24	66	63
MARKETING YEAR	MECHANICAL DEVICES: (PHOSPHINE PELLET DISPENSER)	5	63	2	8	38
MARKETING YEAR	MECHANICAL DEVICES: (POWER PROBE)	18	50	19	0	1
MARKETING YEAR	MECHANICAL DEVICES: (PROTEIN ANALYZER)	57	65	82	60	70
MARKETING YEAR	MECHANICAL DEVICES: (TEMPERATURE CABLE)	39	14	1	14	9
FALL & WINTER	INSPECTED FOR INSECTS: (CONCRETE SILOS, DO NOT HAVE STRUCTURE)	42	38	74	42	19
FALL & WINTER	INSPECTED FOR INSECTS: (CONCRETE SILOS, MONTHLY)	18	46	9	46	45
FALL & WINTER	INSPECTED FOR INSECTS: (CONCRETE SILOS, WEEKLY)	32	12	5	8	11
FALL & WINTER	INSPECTED FOR INSECTS: (OTHER STRUCTURES, DO NOT HAVE STRUCTURE)	76	44	53	69	27
FALL & WINTER	INSPECTED FOR INSECTS: (OTHER STRUCTURES, MONTHLY)	3	52	14	22	40
FALL & WINTER	INSPECTED FOR INSECTS: (STEEL BINS & TANKS, DO NOT HAVE STRUCTURE)	9	6	17	58	10
FALL & WINTER	INSPECTED FOR INSECTS: (STEEL BINS & TANKS, MONTHLY)	34	59	23	31	47
FALL & WINTER	INSPECTED FOR INSECTS: (STEEL BINS & TANKS, WEEKLY)	33	15	5	4	16
FALL & WINTER	MEASURED TEMPERATURE: (CONCRETE SILOS, DO NOT HAVE STRUCTURE)	42	38	74	42	19
FALL & WINTER	MEASURED TEMPERATURE: (CONCRETE SILOS, MONTHLY)	8	37	4	30	26

PERIOD	PEST MANAGEMENT PRACTICE	% OF OPERATIONS CO	ID	MT	OR	WA
FALL & WINTER	MEASURED TEMPERATURE: (OTHER STRUCTURES, DO NOT HAVE STRUCTURE)	76	44	53	69	27
FALL & WINTER	MEASURED TEMPERATURE: (OTHER STRUCTURES, MONTHLY)	2	40	3	16	22
FALL & WINTER	MEASURED TEMPERATURE: (STEEL BINS & TANKS, MONTHLY)	15	54	4	14	29
FALL & WINTER	MEASURED TEMPERATURE: (STEEL BINS & TANKS, WEEKLY)	32	10	1	4	6
SPRING & SUMMER	INSPECTED FOR INSECTS: (CONCRETE SILOS, DO NOT HAVE STRUCTURE)	42	38	74	42	19
SPRING & SUMMER	INSPECTED FOR INSECTS: (CONCRETE SILOS, MONTH-LY)	18	46	11	46	42
SPRING & SUMMER	INSPECTED FOR INSECTS: (OTHER STRUCTURES, DO NOT HAVE STRUCTURE)	76	44	53	69	27
SPRING & SUMMER	INSPECTED FOR INSECTS: (OTHER STRUCTURES, MONTHLY)	3	52	17	22	34
SPRING & SUMMER	INSPECTED FOR INSECTS: (STEEL BINS & TANKS, DO NOT HAVE STRUCTURE)	9	6	17	58	10
SPRING & SUMMER	INSPECTED FOR INSECTS: (STEEL BINS & TANKS, MONTHLY)	35	58	27	31	45
SPRING & SUMMER	MEASURED TEMPERATURE: (CONCRETE SILOS, DO NOT HAVE STRUCTURE)	42	38	74	42	19
SPRING & SUMMER	MEASURED TEMPERATURE: (CONCRETE SILOS, DO NOT MONITOR)	11	14	21	21	40
SPRING & SUMMER	MEASURED TEMPERATURE: (CONCRETE SILOS, MONTHLY)	8	37	4	30	20
SPRING & SUMMER	MEASURED TEMPERATURE: (OTHER STRUCTURES, DO NOT HAVE STRUCTURE)	76	44	53	69	27
SPRING & SUMMER	MEASURED TEMPERATURE: (OTHER STRUCTURES, MONTHLY)	2	40	3	16	17
SPRING & SUMMER	MEASURED TEMPERATURE: (STEEL BINS & TANKS, DO NOT HAVE STRUCTURE)	9	6	17	58	10
SPRING & SUMMER	MEASURED TEMPERATURE: (STEEL BINS & TANKS, MONTHLY)	17	54	4	14	21

Table 9. Adoption rates of pest management practices by percent by percent of operations for nursery and floriculture production in Western states in 2009. Only practices adopted on 30% or more of operations in either California or Oregon are included in the table. Data obtained from USDA-NASS Pest Management Practices Survey.

PEST MANAGEMENT PRACTICE	% OF OPERATIONS	
	CA	OR
PREVENTION: (BENCHES OR OTHER PLATFORM DEVICES SANITIZED BETWEEN USES)	42	24
PREVENTION: (CONTAINERS SANITIZED BETWEEN USES)	44	24
PREVENTION: (FIELD OR GREENHOUSE BORDERS OR LANES WERE TILLED, MOWED, OR BURNED)	37	63
PREVENTION: (INCOMING STOCK INSPECTED)	57	50
PREVENTION: (INFECTED PLANTS OR PLANT PARTS REMOVED OR PRUNED)	68	90
PREVENTION: (WATER MGMT PRACTICES USED)	43	27
AVOIDANCE: (CROP OR PLANT VARIETY CHOSEN FOR SPECIFIC PEST RESISTANCE)	33	29
AVOIDANCE: (GREENHOUSE SCREENING USED)	34	17
AVOIDANCE: (PLANT DENSITY ADJUSTED)	39	60
AVOIDANCE: (PLANTS ELEVATED)	32	46
AVOIDANCE: (STERILIZED GROWING MEDIA USED)	38	35
MONITORING: (INSECT TRAPS USED FOR PEST DETECTION)	38	8
MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY CONDUCTING GENERAL OBSERVATIONS WHILE PERFORMING ROUTINE TASKS)	79	74
MONITORING: (SCOUTED - FOR PESTS OR BENEFICIAL ORGANISMS BY DELIBERATELY GOING TO THE CROP ACRES OR GROWING AREAS)	31	10
MONITORING: (WEATHER DATA USED TO ASSIST DECISIONS)	58	76
MONITORING: (WRITTEN OR ELECTRONIC RECORDS KEPT TO TRACK THE ACTIVITY OF PESTS)	31	6
SUPPRESSION: (GREENHOUSE RELATIVE HUMIDITY MODIFIED)	44	62
SUPPRESSION: (GREENHOUSE TEMPERATURE MODIFIED)	32	62
SUPPRESSION: (GREENHOUSE VENTILATED)	55	46
SUPPRESSION: (GROUND COVERS, MULCHES, OR OTHER PHYSICAL BARRIERS MAINTAINED)	47	66
SUPPRESSION: (PESTICIDES WITH DIFFERENT MECHANISMS OF ACTION USED TO KEEP PEST FROM BECOMING RESISTANT TO PESTICIDES)	49	26
SUPPRESSION: (PLANT TISSUE DRYNESS MGMT USED)	43	50
SUPPRESSION: (RECOMMENDATIONS FOR PEST CONTROL OR PESTICIDE USE, MOSTLY FROM FARM SUPPLY OR CHEMICAL DEALER)	44	61
SUPPRESSION: (OBTAIN PESTICIDES MOSTLY FROM CHEMICAL DEALER)	78	93
SUPPRESSION: (APPLY PESTICIDES BASED MOSTLY ON A PREVENTATIVE SCHEDULE)	33	26
SUPPRESSION: (APPLY PESTICIDES BASED MOSTLY ON SCOUTING DATA & YOUR ESTABLISHED THRESHOLDS)	41	63

Literature Cited

Alston, Diane and Michael Reding. (1998) Factors influencing adoption and educational outreach of integrated pest management. Journal of Extension [Online]. 36(3). Available online at http://www.joe.org/joe/1998june/a3.html

Alston, Julian M., Kate B. Fuller, Jonathan D. Kaplan and Kabir P. Tumber. (2014) The economic consequences of Pierce's disease and related policy in the California winegrape industry. Journal of Agricultural and Resource Economics. 38:269-297.

Arizona Administrative Code, Chapter 4. Department of Agriculture, Plant Services Division, R3-4-233: Lettuce Mosaic Virus. Available online at http://www.azsos.gov/public_services/Title_03/3-04.htm

Arizona Department of Environmental Quality. 2013. Table 3: 2013 Ground water protection list. http://www.azdeq.gov/environ/water/compliance/download/table3.pdf

Arizona Pest Management Center. (2014) Research-based integrated pest management (IPM) programs impact people communities and the economy of Arizona. University of Arizona, Arizona Pest Management Center. http://cals.arizona.edu/apmc/docs/APMC%20Impact%20narrativep1-4_4-29-14.pdf

Arnold, K., D. Golino and N. McRoberts. (2014) Working with workgroups: A neighborhood approach to area wide disease management of GLRaV-3 in CA vineyards. (Abstract) Phytopathology 103(Supplement 2):9

Aryal, Giri Raj. (2013) Statewide impact of Potato Virus Y on the Idaho economy. M.S. Thesis, University of Idaho, August 2013.

Bentley, W. J. (2009) The integrated control concept and its relevance to current integrated pest management in California fresh market grapes. Pest Management Science. 65:1298-1304.

Brodt, Sonja, Frank Zalom, Rose Krebill-Prather, Walt Bentley, Carolyn Pickel, Joseph Connell, Larry Wilhoit and Marcia Gibbs. (2005) Almond growers rely on pest control advisers for integrated pest management. California Agriculture 59(4):242-248.

Brodt, Sonja, Peter Goodell, Rose Krebill-Prather and Ron Vargas. (2007) California cotton growers utilize integrated pest management. California Agriculture 61(1):24-30.

California Department of Food and Agriculture. California agricultural statistics review. Available online at http://www.cdfa.ca.gov/Statistics/

California Department of Pesticide Regulation. (2014a) Summary of pesticide use report data - 2012. Available online at http://www.cdpr.ca.gov/docs/pur/pur12rep/12sum.htm

California Department of Pesticide Regulation. (2014b) 2013 Pesticide residues in fresh produce. Available online at http://www.cdpr.ca.gov/docs/enforce/residue/resi2013/rsfr2013.htm

Calixto, A., A. Birt, N. Lee, A. Dean, B. Ree and M.K. Harris. (2011) Pecan ipmPIPE: Harnessing the internet for stakeholders in production agriculture. Journal of Integrated Pest Management. DOI: http://dx.doi.org/10.1603/IPM11005

Ellsworth, P. C., A Fournier, W. Dixon, J.C. Palumbo, D.H. Gouge, K. Umeda and J. Peterson. (2012) Enhancing capacity for IPM practice and assessment in Arizona. NIFA IPM Programs: Legacy and impacts. pages 19-21. Available online at http://www.ncipmc.org/resources/ncripm_grants_publications/NIFA%20IPM%20Programs.pdf

Epstein, Lynn and Susan Bassein. (2003) Patterns of pesticide use in California and the implications for strategies for reduction of pesticides. Annual Review of Phytopathology. 41:351-375.

Epstein, Lynn and Minghua Zhang. (2014) The impact of integrated pest management programs on pesticides use in California USA. IN: R. Peshin and D Pimentel (eds.) Integrated Pest Management: Experiences with Implementation, vol. 4 Global Overview, Springer, The Netherlands.

Espino, Luis. A., Chris A. Greer, Randall G. Mutters and James F. Thompson. (2014) Survey of rice storage facilities identifies research and education needs. California Agriculture. 68:38-46.

Fernandez-Cornejo, J., Richard Nehring, Craig Osteen, Seth Wechsler, Andrew Martin and Alex Vialou. (2014) Pesticide use in U.S. agriculture: 21 selected crops, 1960-2008. USDA ERS Economic Information Bulletin Number 124. 84 pages. Available online at http://www.ers.usda.gov/publications/eib-economic-information-bulletin/eib124.aspx

Fuller, Kate B., Julian M Alston and Deborah A. Golino. (2013) The benefits from certified virus-free nursery stock: A case study of grapevine leafroll-3 in the north coast region of California. Robert Mondavi Institute - Center for Wine Economics. University of California. 37 pages. http://vinecon.ucdavis.edu/publications/cwe1306.pdf

Gallardo, R. K. and Q. Wang. (2013) Willingness to pay for pesticides' environmental features and social desirability bias: The case of apple and pear growers. Journal of Agricultural and Resource Economics. 38(1):124-139.

Geisseler, Daniel and William R. Horwath. (2013) Production of processing tomatoes in California. California Department of Food and Agriculture, Fertilizer Research and Education Program. 4 pages. Available online at http://apps.cdfa.ca.gov/frep/docs/Tomato_Production_CA.pdf

Goldberger, Jessica. (2010) Enhancing biological control to stabilize western orchard IPM systems - survey summary report: The experiences and perspectives of California walnut growers. 6 pages. Available online at http://enhancedbc.tfrec.wsu.edu/

Goldberger, Jessica. (2011a) Enhancing biological control to stabilize western orchard IPM systems - survey summary report: The experiences and perspectives of Oregon pear growers. 6 pages. Available online at http://enhancedbc.tfrec.wsu.edu/

Goldberger, Jessica. (2011b) Enhancing biological control to stabilize western orchard IPM systems - survey summary report: The experiences and perspectives of Washington pear growers. 6 pages. Available online at http://enhancedbc.tfrec.wsu.edu/

Goldberger, Jessica R., Nadine Lehrer and Jay F. Brunner. (2011) Azinphos-methyl (AZM) phase-out: Actions and attitudes of apple growers in Washington state. Renewable Agriculture and Food Systems. 26(4):276-286.

Goldberger, Jessica R., Nadine Lehrer and Jay F. Brunner. (2013) Adoption of organophosphate alternatives in Washington apple IPM programs: Survey evidence from pest management consultants and growers. Journal of Integrated Pest Management. 4(3):8.

Goodhue, Rachael E. Karen Klonsky and Sandeep Mohapatra. (2010) Can an eduation program be a substitute for a regulatory program that bans pesticides? Evidence from a panel selection model. American Journal of Agricultural Economics. 92(4):956-971.

Grasswitz, T.R. and Gomez, R.E. (2012) Integrated Pest Management (IPM): Addressing small-scale farmer needs in New Mexico. Poster presented at the 6th National Small Farm Conference. Memphis, TN. September 18-20, 2012.

Grogan, K.A. and Rachel E. Goodhue. (2012) Citrus growers vary in their adoption of biological control. California Agriculture 66:29-36.

Gubler, W.D., R.J. Smith, L.G. Varela, S. Vasquez, J.J. Stapleton and A.H. Purcell. (2014) Powdery mildew. IN: UC IPM Grape Pest Management Guidelines. Available online at http://www.ipm.ucdavis.edu/PMG/r302100311.html

Hara, Arnold H. (2014) Hawai'i IPM: Annual UH Extension IPM report. Available online at http://www.ctahr.hawaii.edu/haraa/

Hillis, Vicken, Mark Lubell, Kendra Baumgartner and Jonathan Kaplan. (2013) Adoption of preventative disease management practices. Center for Environmental Policy and Behavior, University of California Davis. Available online at http://environmentalpolicy.ucdavis.edu/project/adoption-preventative-plant-disease-management-practices

Jones, Vincent P., Jay F. Brunner, Gary G. Grove, Brad Petit, Gerald V. Tangren and Wendy E. Jones. (2010) A web-based decision support system to enhance IPM programs in Washington tree fruit. Pest Management Science. 66:587-595.

Kaiser, Clive, Len Coop and Kevin Masterson. (2013) Impacts and outcomes of integrated pest management extension programs in Umatillo County, Oregon. HortScience 48(9) Supplement:S242.

Koike, S.T. and R.M. Davis. (2009) Lettuce Mosaic. In: UC IPM Lettuce Pest Management Guidelines. Available online at http://www.ipm.ucdavis.edu/PMG/r441101011.html

Langham, M.A.C., H.F. Schwartz, S.A. Toin, J. Golod, J. LaForest and K.F. Cardwell. (2011) Legume ipmPIPE: A new option for generating summarizing, and disseminating real-time pest data to stakeholders. Journal of Integrated Pest Management. DOI: http://dx.doi.org/10.1603/IPM11003

Lybbert, Travis J., Nicholas Magnan and W. Douglas Gubler. (2012) Multi-dimensional responses to risk information: How do winegrape growers respond to disease forecasts and to what environmental effect? Robert Mondavi Institute - Center for Wine Economics. University of California. 48 pages. Available online at http://vinecon.ucdavis.edu/publications/cwe1203.pdf

Monterey County Agricultural Commissioner. (2014) Host-free and disease control programs. Available online at http://ag.co.monterey.ca.us/pages/host-free-disease-control-programs

Murray, Marion, Diane Alston and Dan Drost. (2011) Utah vegetable industry integrated pest management survey. 4 pages. Available online at http://utahpests.usu.edu/ipm/htm/vegetables/vegetable-research-reports

Murray, Marion and Diane Alston. (2011) Utah tree fruit survey summary. 6 pages. Available online at http://www.utahpests.usu.edu/ipm/htm/fruits/tree-fruit-report

Naranjo, Steven E. and Peter C. Ellsworth. (2009) Fifty years of the integrated control concept: Moving the model and implementation forward in Arizona. Pest Management Science. 65:1267-1286.

Ohmart, Cliff. (2008) Innovative outreach increases adoption of sustainable winegrowing practices in Lodi region. California Agriculture. 62(4):142-147.

Ohmart, Cliff and Andrew Arnold. (2011) Member grower practices survey, alignment of practices with existing certification programs and transportation footprint of shipping flowers from South America to U.S. destinations. California Cut Flower Commission. 35 pages. Available online at http://www.ccfc.org/files/2012/SureHarvest%20Final%20Report%20to%20CCFC%20edited%2010_20_11.pdf

Olsen, J.L. (2002) Oregon State University's integrated pest management program for the Oregon hazelnut industry. HortTech 12(4): 623-625

Palumbo J.C. (2014) Lettuce insect losses and insecticide use summary 2004-2013. Vegetable IPM Update. University of Arizona Cooperative Extension. Vol. 5 No. 8 https://extension.arizona.edu/sites/extension.arizona.edu/files/resources/041614%20Lettuce%20Losses_Insecticide%20Usage%20Surveys_%209%20yr%20summary.pdf

Palumbo, John C. and Steven J. Castle. (2009) IPM for fresh-market lettuce production in the desert southwest: the produce paradox. Pest Management Science. 65:1311-1320.

Research Group LLC, The. (2014) Economic impact from selected noxious weeds in Oregon. Oregon Department of Agriculture Noxious Weed Control Program. 186 pages. Available online at: http://www.oregon.gov/ODA/shared/Documents/Publications/Weeds/ORNoxiousWeedEconomicImpact.pdf

Schwartz, Howard F., Diane Alston, Jeff Alwang, Michael Bartolo, Tamla Blunt, Charles O. Boateng, Bonnie Bunn, Chris S. Cramer, Whitney Cranshaw, Jeff Davidson, Mike Derie, Jeff Doran, Keith Douce, Dan Drost, Lindsey J. du Toit, J. Gao, Thaddeus Gourd, Beth Gugino, Bob Hammon, Janet Hardin, Mary Hausbeck, George Jibilian, Jed Lafferty, Joseph LaForest, Mark S. McMillan, S. Krishna Mohan, Jarrod Morrice, Brian A. Nault, Claudia Nischwitz, George Norton, Kristen Otto, Hanu R. Pappu, Mike Petersen, Ram Sampangi, Brenda Schroeder, Will Secor, Stephanie Szostek Ned Tisserat, Mark E. Uchanski, Jim VanKirk, Tim Waters, Prissana Wiriyajitsomboon and Carrie Wohleb. (2014) Onion ipmPIPE: A coordinated effort to improve the management of onion thrips and Iris yellow spot virus for the U.S. onion industry. Plant Health Progress 15(4):172-183. Available online at doi:10.1094/PHP-FE-14-0026

Stone, W.W., R.J. Gilliom and J.D. Martin. (2014) An overview comparing results from two decades of monitoring for pesticides in the nation's streams and rivers, 1992-2001 and 2002-2011. U.S. Geological Survey Scientific Investigations Report 2014-5154. 23 pages. Available online at http://dx.doi.org/10.3133/sir20145154.

SureHarvest. (2013) California pear sustainability practices survey. 35 pages. Available online at http://www.calpear.com/_pdf/2013%20Pear%20Sustainability%20Report%20Summary%20FINAL.pdf

Tumber, Kabir P., Julian M. Alston and Kate B. Fuller. (2014) "Pierce's disease costs California $104 million per year." California Agriculture. 68(2):20-29.

United States Bureau of Labor Statistics. Consumer Price Index. U.S. Inflation Calculator. http://www.usinflationcalculator.com/

United States Department of Agriculture - Agricultural Marketing Service, Science and Technology Program. (2014) Pesticide Data Program, Annual Summary, Calendar Year 2012. 183 pages. Available online at http://www.ams.usda.gov/AMSv1.0/pdp

United States Department of Agriculture - National Agriculture Statistics Service. (2014a) Agricultural Chemical Use Program: Pest Management Surveys. Available online at http://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Chemical_Use/

United States Department of Agriculture - National Agriculture Statistics Service. (2014b) California Agricultural Statistics. Available online at http://www.nass.usda.gov/Statistics_by_State/California/Publications/California_Ag_Statistics/Reports/

United States Government Accountability Office. (2001) Agricultural pesticides: Management improvements needed to further promote integrated pest management. GAO-01-815. 31 pages. Available online at http://www.gao.gov/products/GAO-01-815

United States Government Accountability Office. (2010) Agricultural chemicals: USDA could enhance pesticide and fertilizer usage data, improve outreach, and better leverage resources. GAO-11-37. http://www.gao.gov/assets/320/311986.pdf

VanKirk, James R., Scott A. Isard, Kitty F. Cardwell and Martin A. Draper. (2012) The ipmPIPE: Overview, lessons, opportunities and challenges. Journal of Integrated Pest Management. DOI: http://dx.doi.org/10.1603/IPM11015

Varela, L.G. and R.B. Elkins. (2008) Conversion from use of organophosphate insecticides to codling moth mating disruption in California pear orchards. Acta Horticulturae 800:995-960.

Weddle, Patrick W., Stephen C. Welter and Don Thomson. (2009) History of IPM in California pears – 50 years of pesticide use and the transition to biologically intensive IPM. Pest Management Science 65:1287-1292.

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