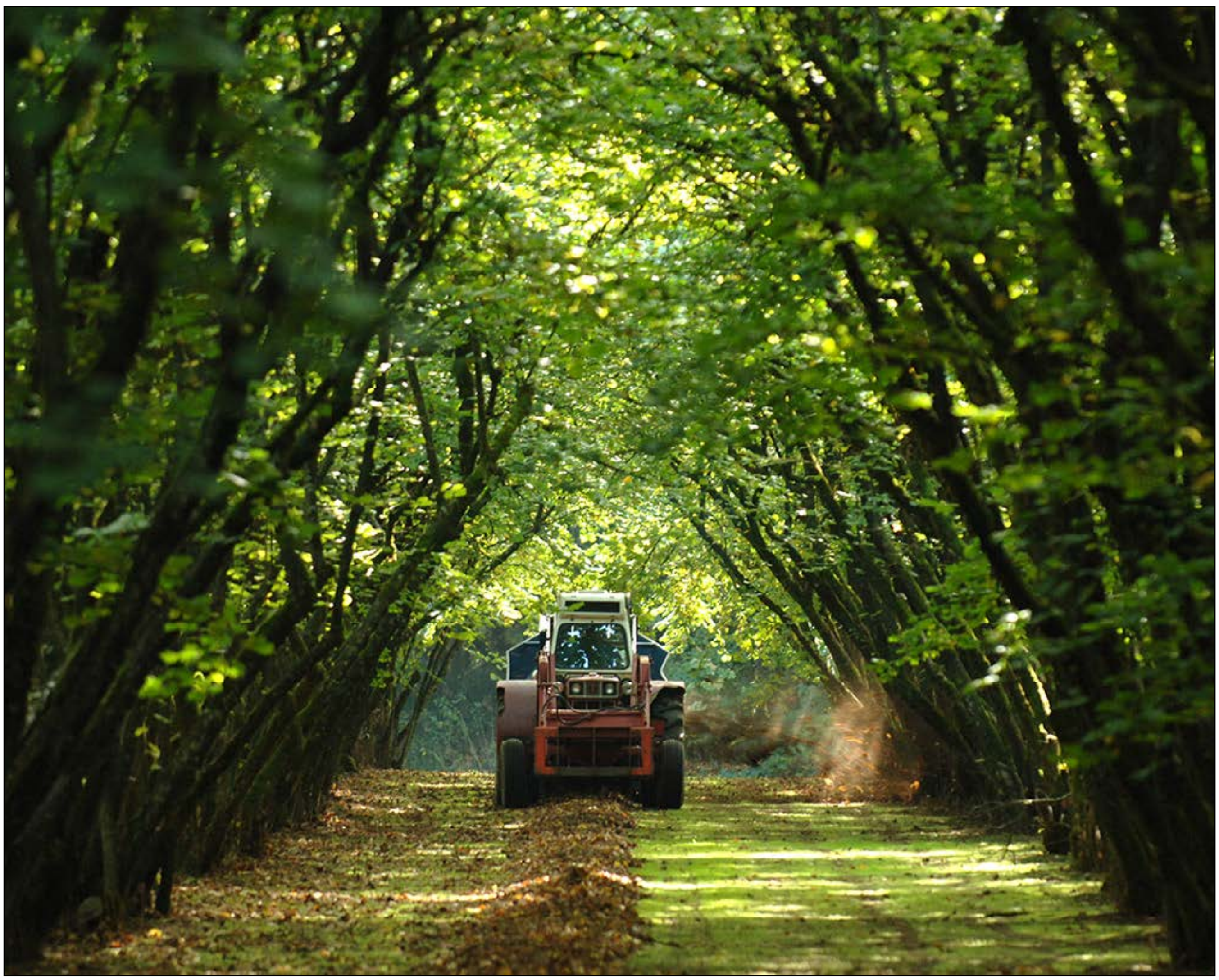
OREGON STATE UNIVERSITY EXTENSION SERVICE

An Integrated Pest Management Strategic Plan for HAZELNUTS in Oregon and Washington

Katie Murray and Paul Jepson



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Process for this Integrated Pest Management Strategic Plan ("IPMSP")

In a proactive effort to identify pest management priorities and lay a foundation for future strategies and increased use of integrated pest management in hazelnut production, growers, commodity-group representatives, pest control advisors, processors, university specialists, and other technical experts from the hazelnut industry in Oregon and Washington formed a work group and assembled this plan. Members of the group met for a day in February 2018, in Salem, Oregon, where they discussed and reached consensus about this plan. It outlines major pests, current management practices, critical needs, activity timetables, and efficacy ratings of various management tools for specific pests in hazelnut production. The result is a strategic plan that addresses many IPM and pest-specific critical needs for the Oregon and Washington hazelnut industry.

A list of top-priority critical needs was created based on a group voting process at the work group meeting. This was drawn from an assessment of all the needs that appear throughout the document, which were compiled from work group members. A list of broader IPM needs was also compiled, based on work group-cited needs related to specific topics. Crop-stage-specific critical needs are also included, listed, and discussed throughout this publication.

This strategic plan begins with an overview of hazelnut production. The overview is followed by discussion of critical production aspects of this crop, including the basics of IPM in hazelnut production in this region. Each pest is described briefly, with links provided for more information about the biology and life cycle of each pest. Within each major pest grouping (insects, diseases, and weeds), individual pests are presented in alphabetical order, not in order of importance. The remainder of the document is an analysis of management practices and challenges organized by crop life stage in an effort to assist the reader in understanding whole-season management practices and constraints. Current management practices are presented using a "Prevention, Avoidance, Monitoring, and Suppression" (PAMS) framework to place practices within a simple IPM classification and to demonstrate areas where additional tools or practices may be needed. For more information, see Appendix F, "Using PAMS Terminology" (page 56).

Trade names for certain pesticides are used throughout this document as an aid for the reader. The use of trade names in this document does not imply endorsement by the work group or any of the organizations represented.

Work Group Members

Workgroup members in attendance

Michelle Armstrong, Wilbur-Ellis
Wayne Chambers, grower
Jeff Choate, Oregon State University Extension Service, Lane County
Brian Holmquist, Holmquist Hazelnuts
LeRoy Kropf, grower
Peter Kuenzi, Pratum Coop
Betsey Miller, Entomology, Oregon State University
Matt Miller, grower
Marcelo Moretti, Weed Science, Oregon State University
Meredith Nagely, Oregon Hazelnut Commission
Jeff Newton, Christensen Farm
Polly Owen, Oregon Hazelnut Commission
Andrew Pokorny, Crop Production Services
Jay W. Pscheidt, Botany and Plant Pathology, Oregon State University
Vaughn Walton, Entomology, Oregon State University
Nik Wiman, Horticulture, Oregon State University

Others in attendance

Amanda Crump, Western Integrated Pest Management Center
Dan Edge, Associate Dean, Oregon State University
Paul Jepson, co-facilitator, Integrated Plant Protection Center, Oregon State University
Tunyalee Martin, University of California IPM Program
Katie Murray, facilitator, Integrated Plant Protection Center, Oregon State University

Contributing members not present at meeting

Joe DeFrancesco, Integrated Plant Protection Center, Oregon State University

2018 Updates to 2006 Summary of Critical Needs

Research

- Cultivar development, with emphasis on resistance to eastern filbert blight disease.

  Continuation of a robust breeding program is critical for eastern filbert blight disease management and management of other pests that can severely affect the viability of the hazelnut industry in Oregon and Washington.

  2018 update: New, resistant cultivars have been developed, but potential new eastern filbert blight isolates continue to pose challenges to resistant cultivar development. Because many of these cultivars are only single-gene resistant, stacked gene resistance (horizontal as well as vertical) is needed.

- Development and refinement of management techniques for control of eastern filbert blight disease in existing orchards.

  This disease is widespread and devastating, reducing yields and eventually causing death in both young and old trees. Management of eastern filbert blight in established orchards with susceptible cultivars is critical.

  2018 update: This remains a top priority of the Oregon Hazelnut Commission, and is a continuing need. New chemistries and combinations for control are needed, as well as monitoring performance of the new eastern filbert blight resistant varieties. Although pruning management has improved, unmanaged orchards remain a major source of inoculum.

- Continued investigation of the biology, ecology, and management of filbertworm.

  Filbertworm is the most serious insect pest in hazelnuts. Feeding reduces nut quality and yield. Filbertworm is a perennial problem and occurs in virtually all hazelnut orchards.

  2018 update: While this remains the most serious insect pest in hazelnut, there has been progress. Research on pest biology and ecology are under way, and a commercially available mating disruption product is now available with increasing utilization, especially with organic producers. Before mating disruption was available, organic growers had no viable options.

- Development of an integrated pest management program that emphasizes the protection of beneficial arthropods that occur naturally in hazelnut orchards.

  Beneficial arthropods play an important role in the management of insect pests in hazelnut orchards. Learning more about beneficials and how to protect them will help reduce pesticide use and other pest management inputs.

  2018 update: The mating disruption program began based on this need. Softer insecticides were more expensive, and mating disruption was more economical. A program for protection of beneficials remains a need, including protection of predators for pests such as brown marmorated stink bug, Pacific flatheaded borer, and aphid, as well as the impacts of orchard floor leaf management on beneficial insects.

- Investigation of the biology, ecology, and management of the filbert weevil.

  The filbert weevil is a new pest in hazelnut orchards, and much needs to be learned about its behavior and management. Some of the damage attributed to the filbertworm may be caused by the filbert weevil.

  2018 update: The filbert weevil is not a major pest issue in hazelnut orchards.

Regulatory

- Ensure that regulators and pesticide registrants include hazelnuts in nut group registrations and labels.

  Tolerances established for almonds and pecans, the representative commodities in EPA Crop Group 14 (Tree Nuts), enables hazelnuts to be included in registrations, but hazelnuts are often overlooked when labels are written.

  2018 update: Hazelnuts are now part of Crop Group 14, and the industry has gained several new fungicide registrations under this designation, but this remains an issue.

- Retain the registration for chlorpyrifos (Lorsban), which plays a unique and important role in insect pest management in hazelnut orchards.

  The fuming action of chlorpyrifos enhances control of insects that are difficult to control due to their habit of protecting themselves in rolled leaves (such as leafroller larvae).

  2018 update: Chlorpyrifos is no longer a go-to chemistry for leafroller, but remains an important product for the industry in controlling other insect pests, such as omnivorous leaftier and Pacific flatheaded borer.

- Simplify and streamline the Section 18 process to ensure emergency use of pesticides in a timely manner.

  Section 18 registrations have in the past been very useful in helping to avert crop and economic losses, but the process is slow and cumbersome.

  2018 update: Some section 18 registrations have been developed and submitted, but the process remains slow and cumbersome, which poses a barrier to growers.

- Add filbert bud mite as a pest on the Envidor (spirodiclofen) label.

  Spirodiclofen is registered for use in hazelnuts, but the filbert bud mite is not listed on the label.

  2018 update: This was achieved, but the product is now used sporadically on bud mite, as efficacy is only fair and timing is complex.

- Continue legislative support for current right-to-farm laws.

  Growers rely on right-to-farm laws to help them remain productive as challenges from the rural-urban interface continue to grow.

  2018 update: Production practices such as airblast spraying, dust management, and aerial application continue to pose a challenge with production near urban areas.

Education

- Communicate to regulators and legislators the importance and necessity of maintaining the registration of chlorpyrifos, which plays a unique role in a hazelnut IPM program.

  2018 update: This product remains in use, as of the publication of this plan.

- Continue to communicate to growers the latest research findings and continue to educate them about pest management strategies that can be used in hazelnut orchards.

  2018 update: This is an ongoing need for the industry.

- Educate growers about best management practices that can be used in their orchards and about how to communicate those practices to neighbors, legislators, and the general public.

2018 update: This is an ongoing need for the industry.

- The urban-rural interface is a major issue where hazelnuts are grown. Maintain good communication with neighbors and the community about the best management practices that are used in hazelnut production.

  2018 update: This is an ongoing need for the industry.

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Top-Priority Critical Needs, 2018

The following critical needs were voted top-priority by the work group members present at the meeting. Crop-stage-specific aspects of these needs, as well as additional needs, are listed and discussed throughout the body of the document.

Research topics

- Research best practices for irrigation amount and timing (including when to stop) with respect to impacts in intercropping, nut fill, bacterial blight, and root-rot management.
- Meet the high demand for the samurai wasp (*Trissolcus japonicus*) that controls brown marmorated stink bug through parasitism, and research the risks versus benefits of this biocontrol method.
- Evaluate ideal levels of foliar nutrition and soil fertility, and the contribution from plant stimulants.
- Research best practices for orchard-floor management to maximize pest management efficacy and minimize pesticide run-off.
- Research application technology best practices that maximize efficacy and minimize pesticide losses.

Regulatory actions

- Address pest management limitations on farms in urban-rural interface areas.
- Develop a cultivar certification program to ensure that new cultivars are true to type.
- Expand registrations from other FRAC classes (class 4 or others) to continue to manage disease resistance, especially for controlling phytophthora root rot, which is controlled with a narrow range of products.
- Register horticultural oils for use in conventional hazelnut production.
- Seek clarification on how to calculate the total number of applications per season when spot-spraying herbicides.
- Offer incentives for using lower-risk management options that are often more costly to growers.

Education

- Educate pest managers on softer management options for leafrollers and other insect pests to reduce reliance on chlorpyrifos.
- Educate pest managers on best practices for soil conservation.
- Educate pest managers on the use of flailing for pest management and weed control.
- Educate pest managers on best practices in application technology.
- Revive and increase engagement with the hazelnut sustainability program.

Hazelnut Production Overview

Although there is a species of hazelnut that is native to the Pacific Northwest, it is the European hazelnut, *Corylus avellana* L., which is grown for commercial nut production in Oregon and Washington. This cultivar was introduced to the region in the mid-1800s. While most people nationally and internationally use the term “hazelnut,” some growers and local residents in the Pacific Northwest use the term “filbert.” Thus, several of the pests associated with hazelnuts, such as “filbertworm” and “eastern filbert blight,” carry this moniker.

While the hazelnut tree itself is quite hardy, satisfactory crops are produced only under moderate climatic conditions. Hazelnuts grow best on deep, river-bottom soils but also grow well on a wide variety of other soil types. Both the soils and climate in the western regions of Oregon and Washington are well suited to hazelnut production.

The Willamette Valley region of western Oregon produces over 99 percent of U.S. hazelnuts, with hazelnuts ranking as Oregon’s 11th most valuable agricultural commodity. In 2016, Oregon produced approximately 44,000 tons of hazelnuts from 37,000 producing acres, with a value of $118.8 million. Washington produces a small amount of hazelnuts. This combined Oregon-Washington production represents about 5 percent of the world’s hazelnut production, with Turkey and Italy being the top global producers.

In Oregon, the majority of the production takes place in the Willamette Valley in western Oregon, located between the Cascade Mountains and the Coast Range. As of November 2017, Marion County has the most acreage, at 16,914 acres, followed by other Willamette Valley counties: Yamhill, Linn, Polk, Clackamas, Washington, Lane, Benton, Douglas, and Multnomah.

Commercial hazelnut production in Washington occurs in the western part of the state. The two main production areas are in Clark County in the southern part of the state near the Oregon border, and in Whatcom County in the northern part of the state near the Canadian border. Higher land costs and cooler winter temperatures limit Washington’s hazelnut production.

There is a growing national and international demand for organic hazelnuts. Although there is a small amount of organic acreage in Oregon and Washington, the expansion of organic acreage has been limited primarily by the challenge of controlling filbertworm organically while maintaining a profit. The Pacific Northwest hazelnut industry is interested in developing a cost-effective organic hazelnut production system, but this remains a challenge.

Although hazelnuts are produced in orchards as a single-stem tree, the plant grows naturally as a bush or multi-stemmed shrubby tree. In hazelnut production, suckers growing at the base of the tree that would normally fill in to create a shrubby tree are removed throughout the year to maintain a single-stemmed tree. Hazelnut trees can attain a height of over 40 feet when planted in good soil and managed with proper pruning, fertilization, and pest control practices.

Female hazelnut flower clusters begin to form on the current season’s growth, usually in midsummer. They are first noticeable in November or December, and reach maturity (open blooms) during the winter. Male flowers (catkins) also form early in the growing season and can be first seen in midsummer, but they don’t reach maturity until winter. Pollination can occur anytime between late November and early March, but peak pollination occurs during the winter, usually in January and February. Extreme cold temperatures (less than 10 to 15 degrees Fahrenheit) can damage male and female flowers and reduce crop yield, but the mild winter weather common in western Oregon and Washington is generally conducive to a successful and profitable hazelnut crop.

Hazelnuts are not self-fertile but are cross-pollinated. Their pollen is dispersed by wind. Pollinizer cultivars are planted within the hazelnut orchard so that the cultivar of the main crop is no more than 50 feet from a pollinizer tree. Pollinizer cultivars must be compatible with the recipient cultivar, should yield well, must produce nuts that have similar characteristics to the main cultivar, and most importantly, must be resistant to eastern filbert blight disease. Often two or three different pollinizer cultivars are dispersed within the orchard to ensure a ready supply of pollen during the long period of female flower receptivity. The cultivar Daviana is a common pollinizer in older orchards that are planted with the cultivar Barcelona. However because of Daviana's extreme susceptibility to eastern filbert blight, growers have aggressively replaced it with other compatible pollinizers over the years.

Historically, 60 to 70 percent of Pacific Northwest hazelnut orchards were planted with the cultivar Barcelona, an older cultivar with many good attributes, including good yields, a vigorous and upright growth habit, and round-shaped nuts that are medium to large in size, have excellent flavor, and are suitable for both the kernel and the in-shell market. Barcelona does, however, have some undesirable characteristics, the most important of which is that it is only moderately resistant to eastern filbert blight disease.

Since 2007, the Oregon State University hazelnut breeding program has been developing cultivars to improve on Barcelona. These have many desirable characteristics, such as heavy annual production, fewer blanks and kernel defects, and resistance to eastern filbert blight.

Early cultivar releases from the breeding program, such as Santiam, Lewis, Clark, and Sacajawea, and their pollinizers including Delta, Epsilon, Gamma, and Zeta show quantitative resistance to eastern filbert blight. More recently, newer releases expressing greater resistance to eastern filbert blight and exceptional qualities include Dorris, Felix, York, Jefferson, Wepster, McDonald, Yamhill, and PollyO. Some of these commercial varieties pollinate each other, thus eliminating the need for a pollinizer that generally produces a lesser quality nut. With a total of 67,000 acres planted as of November 2017, the percent of Barcelona has dropped by half, to around 30 percent.

Hazelnut trees do not produce a commercially harvestable crop until the third to fifth year in the ground, and it can take trees 10 to 12 years to reach full production. If they are well-managed, hazelnut trees can remain productive for 40 to 60 years or even longer. Since nuts are produced mostly on new wood, adequate fertilization and pruning are necessary to increase and maintain tree vigor. In addition to annual applications of nitrogen and potassium, trees respond to foliar- or soil-applied boron, which increases nut set.

Hazelnuts begin to drop to the ground during the month of September. Prior to nut drop, the orchard floor is made level and smooth, and weeds are flail-mowed to facilitate harvest. Harvest generally occurs during October and is usually a two-step operation. Once most of the nuts have fallen, nuts on the orchard floor are mechanically swept into a windrow between the tree rows. Then a harvesting machine picks up the nuts from the windrow and drops them into a tote box or trailer. New harvesters are slowly being adopted that do not require windrows.

The nut harvester also separates out twigs, leaves, and other debris as the nuts are being harvested. The nuts are then transported out of the orchard to a cleaning and drying facility. Once dried, the nuts are sold in the shell, or shelled and sold as kernels or further-processed products. The 10-year average (ending in 2017) indicated 6 percent sold on the domestic inshell market, 60 percent sold in the export inshell market, and 34 percent sold on the kernel market. Most kernels are sold domestically.

As of 2017, the 10-year average of nuts produced per acre was 2,480 pounds. Production from mature orchards ranges from less than 1,000 pounds to more than 4,000 pounds of dry nuts per acre depending on soil type and management practices. The value of the nut crop varies from year to year, and the price per pound that Pacific Northwest growers receive is strongly influenced by worldwide hazelnut prices. In the past 5 years, the price per pound received by Oregon and Washington growers has ranged from $1.02 to $1.80, with an average of $1.38.

Integrated Pest Management Overview in Hazelnut Production

The hazelnut industry relies heavily on integrated pest management to control insects, diseases, vertebrates, and weeds that are found in hazelnut orchards while reducing the amount of pesticides that are used for pest management. IPM techniques used in hazelnut orchards are based on both scientific research and grower experience. The hazelnut industry has strongly supported IPM research for more than five decades.

Advances in insect management practices have included the development of monitoring techniques and treatment thresholds for filbert aphid and filbert leafroller, which have reduced prophylactic insecticide applications. Advances have also included the use of pheromone traps and a degree-day model for filbertworm, which permit precise, targeted treatments for this pest. The most valuable result of this IPM approach has been the successful identification and introduction of a filbert aphid parasitoid, *Trioxys pallidus*. This parasitoid, a small Braconid wasp, has provided nearly complete biological control of the filbert aphid and has almost eliminated insecticide use for this pest. Natural biological control of other hazelnut pests may also be enhanced by the aphid biocontrol program, because the elimination of aphicides improves survival of predators and parasitoids that attack leafrollers and filbertworm.

A potential biocontrol has also been identified for a newer hazelnut pest, the brown marmorated stink bug. A parasitic samurai wasp (*Trissolcus japonicus*) has shown success in parasitizing eggs. Continued research on this potential will be critical, because research has shown that pesticides are only a short-term solution for brown marmorated stink bug and will kill beneficial insects, including the samurai wasp.

It is especially important to preserve and enhance biological control of the filbert aphid. Resurgence of filbert aphid populations in recent years indicates a need for further research on cultural techniques to improve survival of *Trioxys pallidus*. Research is also needed to test new pesticides for adverse effects on this filbert aphid parasitoid and to determine the impact on hazelnut production of the recently introduced large hazel aphid (also known as the hazelnut aphid), which is not controlled by *Trioxys pallidus*. Research on the natural biological control and improved chemical control of pests such as filbert leafroller and filbertworm would have direct benefits (reducing insecticide use for these pests) and indirect benefits (enhancing survival and biocontrol success of *Trioxys pallidus)*. Research has shown that mating disruption can reduce the amount of insectide applied for filbertworm by up to 75 percent. This reduction in pesticides has the indirect benefit of preserving natural enemies of aphids (including *T. pallidus*). In a 5-year study, orchards managed with a combination of mating disruption and border sprays and/or target sprays saw a significant reduction in aphid populations, and a significant increase in parasitism by *T. pallidus*.

Eastern filbert blight disease (EFB) is the most serious, widespread, and limiting pest found in hazelnut orchards. It reduces nut yield and tree vigor and kills all but the roots of the tree. Left uncontrolled, it spreads rapidly from tree to tree and orchard to orchard. EFB, caused by the fungus *Anisogramma anomala*, was not confirmed in Pacific Northwest hazelnut orchards until the early 1970s. It is suspected that the disease was introduced on infected nursery stock.

Much time and money has been spent on research to understand the biology, ecology, and management of EFB. An integrated approach has been found to be the most successful method of managing and mitigating the effects of this disease. Growers are constantly scouting for disease symptoms. When they are discovered, infected twigs and branches are pruned out and burned. New growth is protected with carefully timed fungicide sprays. Most importantly, the Oregon State University breeding program, with support from the hazelnut industry, has been developing cultivars that are resistant to EFB while maintaining desirable horticultural characteristics such as yield; nut shape, size, and flavor; tree vigor; and easy removal of husks. New orchards are being planted with EFB-resistant cultivars, and old orchards are seeing the replacement of EFB-susceptible pollinizer trees with resistant ones. Even fewer fungicide sprays may be required in hazelnut production once the industry is comprised of mostly EFB-resistant cultivars.

Other important diseases include bacterial blight (*Xanthomonas arboricola* pv. *corylina*) and root rot. Stressed hazelnuts are more susceptible to bacterial blight, such as when trees are planted on marginal sites or are water stressed in midsummer. There has been an increased incidence of bacterial blight in young hazelnut plantings, which leads some growers to overirrigate, resulting in root rot. However, the causes of root rot are not well known or researched.

Kernel molds are another problem, although less critical than other diseases. Moldy kernel incidence averages 0.5 to 1 percent annually, but mold incidence in individual orchards can often be much higher (from 3 to 10 percent). Various fungi reduce kernel quality, but the degree varies with the causal agent and environmental conditions during symptom development. Mold is often highest if rains are significant in spring or during harvest. Mold can also be a problem when bins filled with nuts are grouped together and left out in the rain before drying. Susceptibility to kernel mold is highly heritable, and can be minimized when selecting new cultivars. The cultivars Lewis and Santiam generally have higher levels of mold than Barcelona in any particular year.

Mature orchards tend to have few weed problems, because shading inhibits most weed establishment. Younger orchards have more light penetration and thus more weeds. Herbicides are used in young orchards, but growers also rely on irrigation management, mulch, and flail mowing to manage weeds. However, controlling suckers, or growth that develops from the root stock, is important for tree growth and health and often requires herbicide applications. Maintaining a vegetation strip between the tree rows and carefully timing mowing events provides habitat for beneficial insects that aid in insect pest management. The IPM techniques hazelnut growers use for weed and sucker management not only provide weed control but also help maintain biological diversity in the orchard.

The IPM practices used in hazelnut production help protect and maintain tree health and improve nut quality and at the same time provide a substantial reduction in pesticide use. Maintaining and improving this successful IPM program for insects, diseases, and weeds is critical for the future of the hazelnut industry.

IPM Critical Needs

The following list of broad IPM needs was compiled based on input from workgroup members. Participants were asked to identify specific needs related to each of the headings in bold.

Development of nonchemical pest management options

- Facilitate cooperation with packers to support producers in allowing for greater risk-taking with nonchemical methods.
- Develop and evaluate effective options for nonchemical and mechanical weed and sucker control, and use of cover crops.
- Incorporate more nonchemical management information into pest management guides.
- Improve the economics of using mating disruption; consider a subsidy program to make this more accessible to more growers.
- Provide more accessible information and better sources for effective non-chemical management products and activities.
- Invest resources into exploring new concepts, such as use of natural predators, mechanical weed control, etc.

Whole-farm and areawide management

- Educate growers about the use of mating disruption for filbertworm control.
- Research filbertworm migration patterns.
- Seek support and collaboration from groups such as Eugene Water and Electric Board (EWEB) in watershed protection.
- Increase communication about pests and management between growers, researchers, and consultants.
- Encourage more collaboration between growers.
- Provide incentives that allow growers to use more costly products.
- Evaluate locations where areawide management could be effectively implemented, and for which pests this would be beneficial.

Beneficial and natural-enemy protection

- Require more products to be protective of beneficials and natural enemies.
- Evaluate the impacts of current management practices on beneficials and natural enemies, and identify specific chemical and timing threats to specific beneficials.
- Educate growers on the benefits of beneficials and pollinators.
- Develop and/or register cost-effective, softer pesticide alternatives for major hazelnut pests to protect beneficials and natural enemies.
- Improve application technology and education to growers.
- Develop easy-to-implement management programs that protect natural enemies and pollinators.
- Increase grower use of mating disruption and cultural controls (flailing, groundcover management, etc.).

- Ensure that there are no hives placed adjacent to hazelnut orchards, or that there is communication and coordination between growers and beekeepers if this happens.
- Educate the public on the lack of insect pollinators in hazelnut orchards.

Certification needs: Hazelnut Sustainability Program

- Demonstrate the potential for an increase in profit with the Hazelnut Sustainability Program.
- Engage processors in this program in an effort to increase margins.
- Increase availability of chemicals from a range of mode-of-action classes.
- Engage global market buyers in the Hazelnut Sustainability Program.
- Increase grower understanding of this program and promote more grower participation through targeted outreach efforts.
- Increase public awareness of industry challenges and concerns, and long-term farm sustainability.
- Make growers aware of the sustainability document and guide.
- Include integrated pest management concepts and practices in the program.

Human health and worker protection

- Determine whether Ziram causes dermal reaction to workers.
- Provide grower and employee training through the Extension Service to address human health and worker protection issues.
- Improve on-farm posting protocols for protecting human health.
- Develop cultivars that require less pesticide use.
- Simplify and then educate growers and farm managers on the new standards.
- Identify and then educate on applicator technologies that reduce drift.
- Provide greater support to farmers on this topic, including accessible classes and trainings.

Water quality

- Educate growers and pest managers on how to avoid possible overapplication of pesticides and the idea that you can often achieve the same control with less product applied.
- Update the nutrient management guide with cultivar-specific information.
- Demonstrate to growers the benefits of grass buffer strips between orchards and waterways, cover crops, and other buffer options that protect water quality and minimize erosion.
- Educate growers on ways to increase pesticide efficacy to protect water quality.
- Determine whether propiconazole is washing out of hazelnut orchards into streams, and pursue mitigations if this is the case.
- Encourage collaboration between various utilities and watersheds to subsidize management practices that protect water quality.
- Determine the impact of leaf cover on pesticide movement to soil and water.
- Research and educate on best practices for orchard floor management.

List of Major Hazelnut Pests

(listed alphabetically)

Insect and mite pests

Aphids (filbert and hazelnut)
Borers (Pacific flathead and shothole)
Brown marmorated stink bug (BMSB)
Big bud mite
Filbertworm
Lecanium scale
Leafrollers
(Obliquebanded [OBLR] and filbert leafroller)
Omnivorous leaftier
Spider mite

Diseases

Bacterial blight
Eastern filbert blight
Kernel molds
Lichen and moss
Root rots: *Phytophthora* **and** *Armillaria*
Trunk cankers and branch dieback
(not eastern filbert blight)
Wood decay

Weeds

Annual bluegrass *(Poa annua)*
Annual ryegrass *(Lolium multiflorum)*
Barnyard grass *(Echinochloa crus-galli)*
Canada thistle *(Cirsium arvense)*
Clover (red, white) (**red:** *Trifolium pratense;*
white: Trifolium repens)
Common dandelion *(Taraxacum officinale)*
Crabgrass *(Digitaria spp.)*
Dock *(Rumex crispus, Rumex obtusifolius)*
Field bindweed *(Convolvulus arvensis)*
Groundsel *(Senecio vulgaris)*
Horsetail *(Equisetum arvense)*
Mallow *(Hibiscus trionum)*
Mayweed (dog fennel) *(Anthemis cotula)*
Pineappleweed *(Chamomilla suaveolens)*
Prostrate knotweed *(Polygonum arenastrum)*
Quackgrass *(Elytrigia repens)*
Sharp-point fluvellin *(Kickxia elatine)*
Wild carrot *(Daucus carota)*
Wild garlic *(Allium vineale)*
Wild onion *(Allium canadense)*
Yellow foxtail *(Setaria pumila)*
Yellow nutsedge *(Cyperus esculentus)*

Vertebrate pests

Beavers
Birds
Deer
Elk
Gophers
Moles
Squirrels
Voles

Invasive and emerging pests

Asian shothole borer
eastern filbert blight
(isolates from other North American regions)
Emerald ash borer
Garden symphylan
Japanese beetle
Light brown apple moth
Pseudomonas
Snails and slugs

Hazelnut Pest Management Timing by Crop Stage

Preplant through planting (includes year prior to planting)

- Bud mite, trunk borers
- Root rots, wet feet, eastern filbert blight, bacterial blight
- Weeds
- Birds, beaver, nutria, deer

Dormancy and pollination (November–February)

- Filbert worm
- Root rots, wet feet, eastern filbert blight, bacterial blight, lichen and moss
- Weeds
- Squirrels, voles

Bud break to shoot elongation (March–May)

- Bud mite, aphids, leafroller, leaftier, scale, trunk borers
- eastern filbert blight
- Weeds

Nut maturation (May–September)

- Aphids, trunk borers, brown marmorated stink bug, filbert worm, spider mite, scale
- Bacterial blight
- Weeds
- Rodents

Harvest through postharvest (September–November)

- Brown marmorated stink bug, filbertworm moth
- Kernel mold, bacterial blight, lichen and moss
- Weeds

Major Hazelnut Pest Descriptions

Insects and mites

Filbert aphid *(Myzocallis coryli)*
Hazelnut aphid *(Corylobium avellanae)*

For pest description information, see: https://pnwhandbooks.org/insect/nut/hazelnut/hazelnut-aphid

These are medium to small greenish aphids that feed on leaves (primarily filbert aphid) and husks (primarily hazelnut aphid), causing honeydew. Infestations can reduce percent fill and size of nuts. Damage caused by aphids can be cumulative over seasons, and heavy infestations should be controlled.

Big bud mite *(Phytocoptella avellanae; Cecidophyopsis vermiformis)*

For pest description information, see: https://pnwhandbooks.org/insect/nut/hazelnut/hazelnut-big-bud-mite

These are microscopic eriophyid mites that feed on leaves, flower buds, and catkins. Buds swell to a large size before they die and fall off. Infested buds do not produce nuts and can cause vegetative growth abnormalities. The Oregon State University hazelnut breeding program selects against bud mites, so blasted buds are less common in recent cultivar releases than in some legacy hazelnut varieties.

Brown marmorated stink bug *(Halyomorpha halys)*

For pest description information, see: https://pnwhandbooks.org/insect/nut/hazelnut/hazelnut-brown-marmorated-stink-bug

Brown marmorated stink bug is an invasive pest that is becoming an increasing problem on hazelnuts in the Willamette Valley. These insects can feed on vegetative structures or on nuts (shell thickness or hardness does not protect kernels from feeding damage), which can cause blank nuts, shrivel, or corking damage to the kernels.

Filbertworm *(Cydia latiferreana)*

For pest description information, see: https://pnwhandbooks.org/insect/nut/hazelnut/hazelnut-filbertworm

This insect is a key pest of hazelnuts in the Pacific Northwest. It is a close relative of codling moth, one of the most economically significant insects worldwide.

The filbertworm overwinters as a larva in a silken cocoon. These are mainly found under leaves and debris on the ground. Some larvae also overwinter just beneath the soil surface. After mating, the female moths begin to lay single eggs near developing nuts. When the eggs hatch, tiny larvae search out nuts. They burrow into the nut to feed on the kernel for 2 to 4 weeks before they bore their way out. Larval feeding within the nut destroys the kernel. The entry hole into the shell is not often seen, but the much larger exit hole is apparent after the larva has finished devouring the kernel.

Scale insects

Cottony maple scale (*Pulvinaria innumerabilis*)
European fruit lecanium (*Parthenolecanium corni*)
Excrescent scale (*Eulecanium excrescens*)

For pest description information, see: https://pnwhandbooks.org/insect/nut/hazelnut/hazelnut-scale-insect

Scale insects are closely related to aphids, mealybugs, and whiteflies. Like these insects, they also have piercing-sucking mouthparts. Mature scale insects resemble small helmets or bumps on branches, stems, and the underside of leaves. Severe infestations can kill twigs.

Large quantities of honeydew are produced, which causes growth of sooty mold fungus. Sooty mold fungus can impede photosynthesis, severely devitalize plants, and retard growth.

Filbert leafroller *(Archips rosana)*

For pest description information, see: https://pnwhandbooks.org/insect/nut/hazelnut/hazelnut-filbert-leafroller

Damage from these insects begins early in spring, and includes rolling of leaves (for pupation) as well as larval feeding on foliage and buds.

Obliquebanded leafroller *(Choristoneura rosaceana)*

For pest description information, see: https://pnwhandbooks.org/insect/nut/hazelnut/hazelnut-obliquebanded-leafroller

Larvae roll leaves together using silk to create protected feeding sites. Larvae feed on leaves, but may occasionally damage nuts if their feeding site happens to be within a nut cluster or in direct contact with a nut cluster.

Omnivorous leaftier *(Cnephasia longana)*

For pest description information, see: https://pnwhandbooks.org/insect/nut/hazelnut/hazelnut-omnivorous-leaftier

Larvae appear in early spring and roll and feed on leaves or inside buds. The larvae web both leaves and flowers together and feed on developing buds, often resulting in destruction of the terminal growth. This pest has not been a major problem in recent years.

Pacific flatheaded borer *(Chrysobothris mali)*

For pest description information, see: https://pnwhandbooks.org/insect/nut/hazelnut/hazelnut-pacific-flatheaded-borer

In hazelnuts, flatheaded borer has been a problem in young orchards, where small trees are attacked and often killed. Larvae enter the wood, boring out the cambium as they feed. Larval feeding beneath the bark can result in partial or complete girdling and subsequent tree death, but it can take time for the tree to completely die. The feeding site obstructs the flow of water and nutrients from the roots to the leaves and branches. The larvae have done most of the damage by the end of the growing season and they may move to the middle of the trunk to overwinter. In the spring, the larvae pupate and the adult chews its way out of the host. Some larvae may remain in the wood and emerge the following season.

Shothole borer

European shothole borer, pear-blight beetle (*Anisandrus dispar*)

Lesser shothole borer, fruit-tree pinhole borer (*Xyleborinus saxesenii*)

Shothole borer (*Scolytus rugulosus*)

For pest description information, see: https://pnwhandbooks.org/insect/nut/hazelnut/hazelnut-shothole-borer

This complex of small beetle species share the common name alias "shothole borer" because of the characteristic damage caused by entrance or emergence of adult beetles from the woody host, leaving many small holes resembling a shotgun pattern. Borers are especially attracted to unhealthy trees, but healthy trees growing adjacent to blocks of neglected trees also may be attacked, and hazelnut orchards adjacent to woodlands are also at risk.

Spider mite *(Tetranychus* spp.*)*

For pest description information, see: https://pnwhandbooks.org/insect/nut/hazelnut/hazelnut-spider-mite

Spider mites are tiny, eight-legged, noninsect pests that suck juices and devitalize trees. Spider mites tend to occur on the underside of leaves. Webbing accompanies heavy infestations. Leaves become yellow and silver and may more easily sunburn. Spider mites are an increasing problem in hazelnuts, and in some cases severe defoliation can occur.

Diseases, viruses, and pathogens

Bacterial blight *(Xanthomonas arboricola* pv. *corylina)*

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/hazelnut-corylus-avellana-bacterial-blight

Bacterial blight is caused by a bacterium that attacks buds, leaves, branches, and trunks. Occasionally it attacks nuts, but seldom invades roots. Tree mortality due to this disease is commonly found in orchards the first few years after planting. Rain splash or the movement of infected nursery stock spreads the bacteria. Water-soaked spots develop on leaves, and buds may turn brown and fail to leaf out. Lesions may girdle stems and kill them, and may extend into the main scaffold or trunk.

Eastern filbert blight *(Anisogramma anomala)*

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/hazelnut-corylus-avellana-eastern-filbert-blight

This disease is caused by a fungus that has infected hazelnut orchards throughout the Pacific Northwest. The fungus has a life cycle of 2 or more years, including a 12- to 15-month latent period when no symptoms are visible. Infection occurs in wet weather from budbreak through shoot elongation. Infected branches may die suddenly from July to September, when expanding cankers girdle branches and limbs. If diseased limbs are not removed, most of the canopy of susceptible trees is usually dead within 7 to 15 years after the first infection.

Kernel molds

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/hazelnut-corylus-avellana-kernel-molds

Kernel mold is defined as any visible growth of mold, either on the outside or inside of the kernel. In practice, any white, fuzzy mycelial growth is classified as mold. Research on specific causes of "mold" is lacking, and many different fungi are easily isolated from the shell or kernel, with surface sterilization, with or without any specific symptoms, before or after harvest.

Most mold symptoms develop between nut maturation and when kernels are dried postharvest. Fungi reduce kernel quality, but the degree varies with the causal agent and environmental conditions during symptom development.

The most common symptom in Oregon is a necrosis of the kernel tip, which usually extends into the kernel a few millimeters. Kernel tips are blackened and shriveled, partly reducing kernel quality. Internal discoloration of the kernel is another common symptom. Affected kernels change from a normal, opaque white to a translucent, buttery yellow and have a bitter, rancid flavor. The buttery yellow symptom is not always apparent on the kernel surface. Kernel shriveling in combination with sporulation of fungi on the kernel surface is another defect.

Lichen and moss

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/hazelnut-corylus-avellana-mosses-lichens

A number of mosses and lichens grow on hazelnut. None are parasitic. Control may be desirable because ice or snow may accumulate on mosses and lichens and break branches.

Root rots
Phytophthora ("wet feet")
Armillaria

For pest description information, see:
https://pnwhandbooks.org/plantdisease/host-disease/hazelnut-corylus-avellana-wet-feet
https://pnwhandbooks.org/plantdisease/host-disease/hazelnut-corylus-avellana-armillaria-root-rot

The first indication of root rot is usually poor growth of the shoots, together with premature dropping of the leaves. Symptoms above ground are not specific, and include a general decline. One part, side, or section of the tree may be affected at first. This corresponds to the side that is supported by the roots first attacked by the fungus. Trees may live for a number of years before finally dying.

Trunk cankers and branch dieback (not eastern filbert blight)

The Oregon State University Plant Clinic has diagnosed hazelnut cankers of various causes in the last 50 years. Most of these are due to eastern filbert blight, but a few have been attributed to other fungi. These other fungal cankers have not been fully studied to determine specific causes, the extent to which they are a problem in the industry, or the importance they might represent to the industry as a whole.

Wood decay

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/hazelnut-corylus-avellana-wood-decay

Most fungi that cause extensive wood decay of nut trees are classified in the phylum Basidiomycota. Decay in a single tree may be caused by more than one fungal species. Wood decay fungi enter trees primarily through injuries, from pruning, sunburn, lightning, or cultivating equipment. Two types of wood decay occur in living trees: white rots and brown rots. White rots cause moist, soft, or spongy wood that is a lighter color than sound wood. Brown rots of wood are brown, dry, and crumbly, with longitudinal and transverse cracks. Wood decay leads to limb breakage, uprooted trees, trees broken at the soil line during windstorms, or decreased tree vigor and dieback.

Weeds

- Annual bluegrass (*Poa annua*)
- Annual ryegrass (*Lolium multiflorum*)
- Barnyard grass (*Echinochloa crus-galli*)
- Canada thistle (*Cirsium arvense*)
- Clover (red: *Trifolium pratense*; white: *Trifolium repens*)
- Common dandelion (*Taraxacum officinale*)
- Crabgrasses (*Digitaria* spp.)
- Dock (*Rumex crispus*, *Rumex obtusifolius*)
- Field bindweed (*Convolvulus arvensis*)
- Groundsel (*Senecio vulgaris*)
- Horsetail (*Equisetum arvense*)
- Mallow (*Hibiscus trionum*)
- Mayweed (*Anthemis cotula*)
- Pineappleweed (*Chamomilla suaveolens*)
- Prostrate knotweed (*Polygonum arenastrum*)
- Quackgrass (*Elytrigia repens*)
- Sharp-point fluvellin (*Kickxia elatine*)
- Wild carrot (*Daucus carota*)
- Wild garlic (*Allium vineale*)
- Wild onion (*Allium canadense*)
- Yellow foxtail (*Setaria pumila*)
- Yellow nutsedge (*Cyperus esculentus)*

Including also:

- Hazelnut rootstock suckers

The spectrum of weed species that can be found growing in hazelnut orchards varies depending upon soil type and microclimate conditions. Nevertheless, weed management is necessary, both prior to establishing a new orchard and once established. Weed control is important because it helps reduce competition for water and nutrients in young trees. Controlling weeds also assists in managing rodent populations by eliminating or reducing rodent habitat. Mature orchards tend to have fewer weed problems, because shading inhibits weed establishment. However, some perennial weeds, such as wild garlic, thrive under shady conditions.

Vegetation on the orchard floor throughout the winter aids in erosion control and contributes to better surface-water quality. Thus, the area between the tree rows might have a strip of grass sod or other vegetation that facilitates the ingress and egress of farm equipment, and weeds are managed within this strip.

Sucker control is also necessary to help keep the tree as a single-stemmed plant, to remove possible sources of eastern filbert blight infection, and to reduce competition for nutrients. Suckers are controlled with an herbicide when they are 6 to 18 inches tall. Taller suckers must be removed by hand.

Certain herbicides are allowed prior to planting that are not allowed after planting or in a bearing orchard. At and after planting, growers must use herbicides that are specifically recommended on the label for newly planted trees, or are known to be gentle on newly planted trees.

When herbicides are applied after the trees are planted, care is taken to avoid herbicide contact with the tree itself to reduce the likelihood of phytotoxic effects. Cracks or crevices around the tree are filled, and sawdust is applied around the base of the tree to further minimize the risk of herbicide injury. Tree guards are also used to protect trees from herbicide drift.

Spot spraying with a nonselective systemic herbicide is used to manage difficult-to-control perennial weeds. Flail mowing is also used to keep weeds between the tree rows under control, causing carbohydrate starvation and preventing weeds from flowering and setting seed. A preemergence herbicide with long residual properties is desirable so weeds are controlled all season.

Vertebrate pests

- Beavers
- Birds
- Deer
- Elk
- Gophers
- Moles
- Nutria
- Squirrels
- Voles

Several different types of vertebrate pests have the potential to reduce hazelnut tree vigor and nut yields. Deer, elk, gophers, and voles may be problematic throughout most of the year, and their feeding on roots, bark, or terminal growth can reduce vigor or cause plant death in newly planted orchards. Beavers, muskrats, and nutria may be problematic in hazelnut orchards that are located near waterways. They cause damage by feeding on bark, and in the case of beavers, they can cut down the entire young tree. Birds and squirrels have the most impact on yield loss prior to and during harvest, as they can remove a large volume of nuts from the orchard.

Beavers and nutria

Beavers and nutria can chew and girdle trees, and can be a particular problem in orchards located adjacent to waterways.

Birds

Crows and jays (Steller's and scrub jays) congregate in hazelnut orchards and can consume large quantities of nuts. Birds are generally controlled using auditory frightening devices and shooting.

Deer and elk

Deer and elk feed on foliage, twigs, buds, and nuts. This feeding can delay maturity, reduce yield, negatively impact growth, and in severe cases cause the death of young hazelnut trees. Sharpening their antlers damages the bark of young trees. Deer and elk can be year-round pests, during all stages of tree growth.

Various brands of chemical repellants are available that interrupt deer feeding by providing an unpleasant taste or disagreeable odor, but their effectiveness is generally inconsistent. Physical barriers such as fences offer the best control. Though effective, fencing is expensive and usually cost-prohibitive for most growers. Growers who apply for a crop-damage permit are allowed to shoot animals that are causing damage. This method is most effective for solitary deer or low deer pressure within the orchard.

Gophers and moles

Gopher activity in the orchard is indicated not only by chewing marks on the roots and bark, but also by the characteristic crescent-shaped mounds of soil on the surface, created as they burrow under ground. Gophers are especially attracted to orchards that have a succulent cover crop or other vegetation between tree rows. Gophers feeding on roots and tree bark can kill young trees.

Moles do not feed on plant roots or bark, and don't cause direct damage to hazelnut trees. However, the circular mounds they create as they burrow into the soil interfere with mechanical harvesting of the nut crop.

Gophers and moles are controlled using aluminum phosphide. Pellets are applied to holes, burrows, or underground tunnels, and phosphine gas is released. This is effective for gopher control but not very effective for moles. Some growers also burn sulfur in tunnels and holes, which works best when soil moisture is high (when tunnels are slick and sealed). Many growers also use owl boxes and perches for hawks, which helps reduce gopher populations. Trapping can be effective, but it is very time-consuming and impractical. Propane is also used with limited success.

Squirrels (ground squirrels and tree squirrels)

Squirrels like hazelnuts and the bark of young hazelnut trees, causing a reduction in tree vigor and substantial yield loss if populations are excessive. Squirrels remove and eat nuts from trees and from the ground prior to harvest. Squirrels are controlled mainly by trapping, but also with repellants and shooting. A permit is needed for certain squirrel species (such as western and eastern silver gray squirrels). Trapping is effective but time-consuming and impractical, and it cannot eliminate all the squirrels in an orchard.

Voles

Voles, also known as field mice or meadow mice, feed on roots and tree bark near the ground. Their gnawing and chewing can girdle the roots and trunk of the plant. Subterranean feeding activity also creates air pockets along the root zone. The presence of voles is indicated by chewing marks on the tree trunk near the soil line and on roots, by surface runways in row middle vegetation, and by tunnel entrance holes about 1 inch in diameter.

Because voles depend on cover for protection, damage to trees is most severe when there is heavy sod, a cover crop, litter, or snow near the base of the tree. Voles damage hazelnut trees during the fall, winter, and early spring when other food sources are limited. Their population size is cyclic, with peaks occurring about every 2 to 5 years. Severe vole damage can reduce plant vigor, lower nut yields, and even cause plant mortality.

Adjacent-area management (mowing around orchard borders) can help control voles, as well as habitat reduction through mowing in and between tree rows. Plant guards that are placed around the tree trunks to prevent sun scald can also inhibit above-ground vole feeding, but feeding can occur despite the guards. Owl boxes and perches for hawks can reduce populations.

Invasive and emerging pests

Insects, symphylans, and slugs

Asian, or polyphagous shothole borer (genus: *Euwallecea*):

For details on this potential pest, see: https://ucanr.edu/sites/pshb/overview/About_PSHB/

This polyphagous shothole borer, native to southeast Asia, has been found on the coast of California, from Los Angeles to San Diego. The invasive black beetle is smaller than a sesame seed (around one tenth of an inch long). As with other borer species, the female beetles form tunnels in trunks and branches of host trees and lay their eggs inside. The females vector a fungus (*Fusarium euwallaceae*) that grows in these tunnels and provides the food source for adults and larvae. Borers can cause branches to die, and can eventually kill the whole tree. Monitoring this pest and its spread will be important for the hazelnut industry.

Emerald ash borer (*Agrilis planipennis*)

For pest description of *Agrilis planipennis*, and details of the response to the potential for this species to enter Oregon, see: https://digital.osl.state.or.us/islandora/object/osl%3A1013/datastream/OBJ/view

This borer has been found in many states across the eastern and southeastern United States as well as in Boulder, Colorado in 2013. (http://www.emeraldashborer.info). Although only ash species have been attacked by this pest in North America, other host trees may be colonized. Monitoring for this pest and its potential for spread will be important for the hazelnut industry.

Garden symphylans (*Scutigerella immaculata* **Newport**)

For a description and other information about *Scutigerella immaculata*, see: https://pnwhandbooks.org/insect/ipm/garden-symphylan

Garden symphylans are not insects, but members of the class Symphyla. They are small, white, centipede-like soil arthropods that infest many home gardens and agricultural soils in western Oregon and Washington and throughout the United States. They feed on sprouting seeds, roots, and other subterranean plant parts. Economic damage occurs from direct feeding on roots, rhizomes, and tubers, from establishment through plant maturity. Damage can include seedling death, poor growth, stunted plants, and reduced vigor and yield.

Symphylans have been found in hazelnut orchards and have caused economic damage to trees. However, correct diagnosis of symphylan problems is sometimes challenging, since damage may be exhibited in a number of forms, and symphylans are not always easy to find when damage is observed.

Symphylans exhibit large vertical migrations in the soil profile, and they are very difficult to manage, other than by planting nonpreferred hosts in the period prior to orchard establishment.

Japanese beetle (*Popillia japonica*)

The Japanese beetle is highly destructive. It feeds on hundreds of host plants, including hazelnut trees in some regions. Adult beetles feed on foliage and can cause skeletonization and severe defoliation. Monitoring the spread of this pest will be important for the hazelnut industry.

Light brown apple moth (LBAM) (*Epiphyas postvittana*)

The Oregon Department of Agriculture (ODA) caught one light brown apple moth in 2010, two in 2015, and three in 2016. All moths were caught within a 1-square-mile area in Polk County, indicating the presence of a breeding population of LBAM. In 2017, ODA began a LBAM eradication project in this area, which included trapping, mating disruption, and biological pesticide applications. Trapping and monitoring continues for this pest.

Snails and slugs

For basic details of management in Oregon, see: https://pnwhandbooks.org/insect/ipm/slug

Slugs are a key pest in many cropping systems in the agriculture-rich Willamette Valley in western Oregon. They can feed on both underground plant parts and foliage, especially on young plants.

Diseases

Eastern filbert blight isolates from other North American regions

Eastern filbert blight is endemic to eastern North America. It is strongly suspected that a single introduction occurred into Oregon, based on sampling throughout the production region in 2015. Other strains of *Anisogramma anomala* from eastern North America could overcome the single dominant-resistance gene bred into new cultivars and widely planted in the Pacific Northwest. There are restrictions in Oregon on commercial and ornamental hazelnut cultivars imported from out-of-state (OAR 603-052-0825), but other isolates are still feared.

Pseudomonas

Hazelnut bacterial canker, *Pseudomonas avellanae* (*P. syringae* pv. *coryi*), causes a hazelnut decline, and is present in about 1,000 out of the 20,000 hectares of hazelnut orchards in central Italy. It has also been found in northern Greece. The main symptoms include the rapid wilting of twigs, branches, and trees during spring or summer. Characteristically, the leaves remain attached to the twigs after they wither. The Oregon Invasive Species Council has this disease on a list of the 100 least-wanted species.

Weeds

None at this time.

Hazelnut Pest Management Activities by Crop Stage

Preplant through planting (includes the year prior to planting)

Preplant includes soil preparation and pest management activities prior to planting and at planting, as well as cultural or pest management operations that occur immediately after planting. Planting generally takes place between November and February in Oregon. It can be as late as May in some areas of Washington before the ground is warm enough for planting. The major management issue during this stage is managing weeds in preparation for planting.

The site for a hazelnut orchard is carefully considered prior to planting. The soil is amended and prepared to receive hazelnut trees that will remain in the ground for many years. Soil testing is performed for nutrients and for pH, and adjustments are made prior to disking the ground and planting. The soil is ripped or subsoiled if a hardpan exists. Tree and row spacing varies depending on the cultivar planted and the soil type.

Growers use intercropping to protect against soil loss, improve the soil metrics, and reduce weed competition. Intercropped plants are chosen carefully based on how production (fertility, pesticide needs, timing) coincides with hazelnut production practices. Grass seed, wheat, and clover seed are common intercropped plants in hazelnut orchards.

Since trees don't yield a commercially harvestable crop of nuts until the third to fifth year, and full production is not reached until 10 to 12 years after planting, intercropping with a suitable crop or double planting of hazelnut trees (half of which are removed when the trees reach full production) are options to speed economic returns while the orchard is maturing.

Orchard sites are generally not fumigated prior to planting. Perennial weeds are treated weeks or months before the planting date, and growers monitor for insects. Trees are treated prior to or after planting for disease control, particularly for bacterial blight, which causes damage mostly to young trees.

Field activities and pest management decisions that occur during preplant through planting

- Site selection based on soil type
- Land preparation: removal of roots and rock
- Tiling for soil drainage
- Soil testing (for physical characteristics and pH)
- Applying lime to soil
- Herbicide application
- Cultivation
- Testing for symphylans
- Planting trees
- Planting intercrop (if used)
- Grid marking tree rows
- Establishing irrigation
- Fertilization (after planting)

PAMS[1] practice	Preplant through planting: pest management activities	Target pest(s)
Prevention	Use of berms/tiling to improve drainage	Diseases: root rots and wet feet
Avoidance	Careful cultivar selection to ensure quality. Selecting based on: bare root stock versus micro propagated stock, intended use for kernel market or inshell, harvest date, disease resistance. Selecting out low-quality stock	Eastern filbert blight, bacterial blight, insects (bud mite), mold
	Staking trees to ensure vigor and minimize wind/ice damage and bird breakage	Snow, ice, wind, and bird damage
	Tree height topping/heading to control growth and height; develop scaffold limbs	Snow, ice, wind, and bird damage
	Maintain shallow planting depth to encourage healthy roots	Disease control (root rots and wet feet)
	Fertilization to maintain healthy, vigorous trees	Shothole borer, Pacific flatheaded borer, bacterial blight, general pest defense
	Fencing (low, hot wire)	Beaver, nutria
	Fencing (not often economically viable)	Deer
	Application of Surround WP (kaolin clay) as repellant	Deer
	Foliar application of Thiram as repellant (on nonbearing only)	Deer
	Application of blood products as repellant	Deer
Monitoring	Weed and disease monitoring	General weeds and diseases
	Monitoring for anything feeding on emerging leaves	Insects
Suppression	Cultivation	Weeds, symphylans
	Herbicide applications: ■ 2,4 D + triclopyr (Crossbow) ■ Glufosinate (Rely) ■ Glyphosate (Roundup) ■ Oxyfluorfen (Goal) ■ Pendimethalin (Prowl) ■ Simazine (Princep) ■ Triclopyr (Garlon)	Weeds
	Painting trunks	Disease and insect control (shothole borer, Pacific flatheaded borer); sunburn protection
	Applying tree guards	Chemical/sunburn protection
	Mulching around base of trees, with sawdust or compost or both	Bacterial blight, weed control, herbicide damage prevention, retains moisture, prevents stress to trees
	Preplant copper applications to stock	Bacterial blight
	Preplant neonicotinoid treatment (usually imidacloprid)	Trunk borers (shothole borer, Pacific flatheaded borer)

[1] See Appendix F, "Using PAMS Terminology," page 56.

Critical needs for pest management during preplant through planting

Research topics

- Testing and research to determine which pests and diseases are coming from nurseries (possibly symphylans, phytophthora root rot, bacterial blight, others).
- Research the biology of and best management for phytophthora root rot.
- Develop a method for portable, handheld cultivar testing of stock in field to ensure stock is true to intended cultivar.
- Develop a method for DNA testing of blight resistant cultivars to ensure resistant genes are present; lack of trust in the resistant cultivars can lead to unnecessary use of fungicides.
- Establish ideal nutrient needs for young plants to avoid overfertilization.
- Develop irrigation best practices for young plants.
- Breed new cultivars with insect, mite, and multigenetic disease resistance.
- Identify best practices for young orchard weed and sucker control to prevent phytotoxicity on young trees.
- Research the efficacy of neonicotinoid treatment of seedlings (as root drenches or dips) in limiting trunk borer damage.
- Investigate the role of plant vigor in young trees' susceptibility to diseases and pests.
- Investigate best management practices for accelerating nut production.
- Determine best practices for orchard establishment for organic production.
- Research to determine the relative efficacy of various types of trunk guards versus trunk paints.
- Research to discover the unintended impacts of certain management practices (for example, spraying for sucker control can injure tree bark; use of trunk guards can lead to vole/borer damage underneath the guards; impacts of flailing on beneficials and insect pests).
- Research copper resistance in bacterial blight.
- Research the impact of adjuvants used for sucker control on crop safety.
- Develop best practices for insecticide, fungicide, and herbicide resistance management.
- Determine methods for nonchemical orchard floor management to effectively control weeds.
- Research safe and registered pesticides (insecticides, fungicides, and herbicides) to use for intercropping.
- Research on herbicide carryover from previous crops. (For example, are there potential carryover issues with terbacil?)

Regulatory actions

- Strengthen nursery testing standards to ensure clean plant material.
- Develop a cultivar certification program using genetic markers developed by the USDA germplasm lab.
- If found efficacious, use research data to justify labeling neonicotinoids for use preplant.
- Register alternative FRAC groups (such as group 4) for hazelnut for phytophthora root rot. Only products from FRAC group 33 are registered, and resistance could become an issue.

- Clarify and standardize herbicide label language regarding applications before planting, at planting, and at replanting.
- Clarify crop name on regulatory labels to use just one name (hazelnut) and not both filbert and hazelnut.
- Get clarity from Oregon Department of Agriculture regarding the use of pesticides on intercrops such as grass seed, wheat, and clover seed, and the instances where requiring a registration on both hazelnut and the intercrop presents challenges to growers. (Clopyralid [Stinger] and pyrasulfotole + bromoxynil [Huskie] are two examples of products labeled for grasses that might be used as intercrops, but not labeled in hazelnuts).
- Clarify label language to ensure advisory statements are clear regarding the impacts of factors that drive pesticide efficacy, such as weather and temperature.

Education

- To help improve pest management through better-targeted irrigation and nutrition, the industry needs a specialist in these two areas.
- Educate growers and pest managers on strategies to minimize stress in young orchards.
- Educate growers, pest managers, and industry organizations on their respective roles in disseminating and using important and current research and information.
- Educate growers and pest managers on the unintended impacts of management practices (for example, spraying for sucker control can injure tree bark; use of trunk guards can lead to vole and borer damage underneath the guards).
- Educate growers and pest managers regarding the impacts of specific factors that drive pesticide efficacy, such as weather and temperature, and how to find and understand this information from labels.
- Educate growers and pest managers on pesticide application technology, including issues such as calibration and sprayer adjustments based on crop development.

Dormancy and pollination (November–February)

As the days get shorter and the weather gets cooler in the fall, hazelnut trees drop their leaves and go into dormancy. Catkins elongate and female flowers are expressed. Pollination, with the aid of wind, occurs during this timeframe. The ovule is not fertilized until later in the growing season when nut development occurs.

Major pests controlled during dormancy and pollination include bacterial and eastern filbert blight, prevention for Pacific flatheaded borer, general weed management, vole and squirrel management, and moss and lichen control. Moss and lichen do not remove nutrients from the trees, but they collect moisture that increases the weight of the limbs during freezing weather. This can cause limb breakage during heavy, wet snows or ice storms.

Field activities and pest management decisions that occur during dormancy and pollination

- Pruning and destroying pruned wood
- Scouting for disease
- Sanitation
- Flailing leaves
- Postharvest seeding for cover crop

PAMS practice	Dormancy and pollination pest management activities	Target pest(s)
Prevention	Cutting out infested wood	Sanitation for Pacific flatheaded borer; sunlight management
	Cleaning and disinfecting pruners	Bacterial blight
Avoidance	Pruning	Eastern filbert blight, bacterial blight; sunlight management
	Flailing	Insect control (filbert worm)
	Postharvest seeding for cover crop	Weeds
	Chipping and burning pruned wood	Disease and insect control
Monitoring	Scouting	Eastern filbert blight
Suppression	Applications of copper-based products and/or lime sulfur	Moss, lichen

Critical needs for pest management during dormancy and pollination

Research topics

- Research the impacts of moss and lichen to determine the need for control.
- Determine best practices for soil conservation.
- Research the impacts of various orchard floor management activities on pesticide losses and run-off.
- Determine best practices for orchard floor management to minimize pesticide losses off site, including mitigations (such as buffers or grass strips).
- Research best sprayer technology to maximize efficacy and minimize drift.
- Research best pruning practices for light management to increase yield.

Regulatory actions

- Address pest management limitations on farms in urban-rural interface areas.

Education

- Educate growers and pest managers on the importance of flailing for pest management and preemergent weed control.
- Educate growers and pest managers on best practices for soil conservation.
- Educate growers and pest managers on pesticide selection and application technology (such as calibration and nozzle selection) to reduce pesticide impacts to water.
- Educate growers (and general public) on the potential to collaborate with municipalities and other organizations on water quality efforts (such as the Eugene Water and Electric Board [EWEB] and the Willamette Valley Drinking Water Protection Program, slated to begin in 2020).
- Educate growers on available soil and water conservation district programs to help minimize erosion, improve soil health, and improve water quality (such as yamhillswcd.org).
- Revive and increase participation in and engagement with the Hazelnut Sustainability Program.

Budbreak to shoot elongation (March–May)

This crop stage begins with bud break in early spring, continues during the spring as leaves unfurl and become fully formed, and ends when nut maturation begins, usually in late June. Bud break is defined as the stage when half of the buds on a tree show a separation of the leaves out of the buds.

Major pests managed during this crop stage include bud mite, aphids, leafroller, scale, flatheaded and shothole borers, eastern filbert blight, weeds (such as annual ryegrass and annual bluegrass), and sucker control. If using mating disruption for filbertworm, that management begins in this stage as well.

Field activities and pest management decisions that occur during budbreak to shoot elongation

- Orchard floor leveling
- Flailing
- Mowing
- Pruning and destroying pruned wood
- Sucker removal
- Trunk painting
- Soil and foliar fertilization
- Boron application to increase nut set
- Pheromone application for mating disruption
- Placing and monitoring traps for filbert worm
- Insecticide, miticide, fungicide, and herbicide applications
- Scouting and counting for aphid thresholds; scouting for parasitism

Photo by Betsy Hartley, © Oregon State University

PAMS practice	Budbreak to shoot elongation pest management activities	Target pest(s)
Prevention	Pruning and destroying pruned wood	Diseases
Avoidance	Set out pheromone baited traps for monitoring (May–June)	Filbertworm
	Apply pheromone dispensers for mating disruption (May–June)	Filbertworm
Monitoring	Scouting	Eastern filbert blight and bacterial blight
	Scouting and threshold counting	Aphid, leafroller
	Monitoring for parasitoids	Aphid, mites, brown marmorated stink bug
	Monitoring	Big bud mite
	Leaf analysis for nutrients	Biotic and abiotic stressors
Suppression	**Insecticide applications:** ■ Chlorpyrifos (Lorsban) ■ Imidacloprid (Admire, etc.) ■ Spinosyns (Spinetoram [Delegate])	Shothole borer, Pacific flatheaded borer, aphid, leafroller, mites, leaftier
	■ Abamectin (Agri-mek)	Bud mite
	Fungicide applications to prevent infection: ■ Azoxystrobin + propiconazole (Quilt Xcel) ■ Chlorothalonil (Bravo, Echo) ■ Fluxapyroxad + pyraclostrobin (Merivon) ■ Propiconazole (Tilt, Bumper) ■ Propiconazole + trifloxystrobin (Stratego) ■ Pyraclostrobin (Cabrio) ■ Trifloxystrobin (Flint) ■ Ziram	Eastern filbert blight
	Herbicide applications: ■ Indaziflam (Alion) ■ Flumioxazin (Chateau) ■ Glufosinate (Rely) ■ Glyphosate (Roundup) ■ Paraquat (Gramoxone) ■ Diuron (Karmex) ■ Rimsulfuron (Matrix) ■ Carfentrazone (Aim) ■ Simazine (Princep) ■ Pendimethalin (Prowl) ■ Oryzalin (surflan) in young orchards ■ Isoxaben (Trellis) in young orchards	
	Squirrel and vole control: trapping, killing	Squirrels, voles

Critical needs for pest management during budbreak to shoot elongation

Research topics

- Evaluate effective fungicides for controlling eastern filbert blight.
- Evaluate the roles of foliar nutrition, soil fertility, and plant stimulants in tree health and pest management.
- Research on weed and resistance management (for example, managing wild carrot or ryegrass effectively without causing resistance).
- Research the impact of herbicides used for sucker control on crop maturity, specifically 2,4-D.

Regulatory actions

- Register more herbicide active ingredients with different modes of action to combat resistance.

Education

- Educate growers and pest managers on the proper use of Ziram for eastern filbert blight control as part of a disease management program.
- Educate growers and pest managers on best management practices for eastern filbert blight.
- Educate growers and pest managers on softer management options for leafroller and other insects to reduce chlorpyrifos use and protect natural enemies.
- Educate growers and pest managers on a mating disruption program for filbertworm.
- Educate growers on weed and resistance management.

Nut development (May–September)

Flowers that have been pollinated during the winter are fertilized near the end of May through June and nut development begins. The nuts continue to grow in size until the kernels are fully mature, sometime during August or September. Mature nuts drop to the ground beginning in September, continuing into October for some cultivars. To prevent damage to the nuts, vehicles and farm equipment are not driven in the orchard at this time.

The orchard floor is prepared for harvest in August. Preparation involves flail mowing to remove weeds and blanks (shells without kernels that drop prematurely) and releveling of the ground by filling in potholes and smoothing out the soil surface.

Main pests managed during this stage include filbertworm, aphids, spider mites, shothole borer, Pacific flatheaded borer, brown marmorated stink bug, and weed and sucker control. Any pest management must occur before nut drop or after harvest.

Field activities and pest management decisions that occur during nut development

- Pruning (for bacterial blight)
- Irrigation
- Orchard floor management for harvest: leveling, flailing
- Trapping for filbertworm
- Foliar nutrition and fertigation (irrigating with fertilizer)
- Scouting
- Sucker control

Photo by Lynn Ketchum, © Oregon State University

PAMS practice	Nut development pest management activities	Target pest(s)
Prevention	Pruning and destroying pruned wood	Diseases
Avoidance	Flail mowing	Weeds, insects
	Dragging/leveling	Weeds
	Irrigation for young orchards	Bacterial blight
Monitoring	Scouting	Aphids, eastern filbert blight, filbertworm, mites, brown marmorated stink bug
	Trapping	Brown marmorated stink bug, filbertworm
Suppression	■ Cyfluthrin (Tombstone)	Scale control
	■ Acetamiprid (Assail) ■ Imidacloprid ■ Flupyradifurone + Propylene carbonate (Sivanto) ■ Azadirachtin (Aza-Direct) for organic growers	Aphid
	■ Beta-cyfluthrin (Baythroid) ■ Esfenvalerate (Asana) ■ Methoxyfenozide (Intrepid) ■ Tebufenozide (Confirm) ■ Spinosad (Entrust) for organic growers ■ Pyrethrins (Pyganic) for organic growers	Filbertworm
	Pyrethroid sprays, such as: ■ Bifenthrin (Brigade) ■ Zeta-cypermethrin (Mustang)	Brown marmorated stink bug
	■ 2,4-D (Saber) ■ Carfentrazone (Aim) ■ Glufosinate (Rely) ■ Paraquat (Gramoxone)	Sucker control
	Rodent control (especially important with intercropping, which can attract rodents)	Rodents
	Trunk sprays: Chlorpyrifos (Lorsban), pyrethroids	Shothole borer, Pacific flatheaded borer

Critical needs for pest management during nut development

Research topics

- Establish treatment thresholds for spider mites and bud mites.
- Determine best practices for irrigation methods that impact various aspects of production, including intercropping, nut fill, bacterial blight and root rot, and harvest (for example, how long before harvest to stop irrigation).
- Research evapotranspiration and water demand to better understand irrigation needs.
- Address the unmet high demand for the brown marmorated stink bug parasitoid; research how to integrate this into a management program (with respect to pesticide risks, efficacy of parasitoid, etc.).
- Research effective control options, chemical and nonchemical, for hard-to-control weeds such as sharp-point fluvellin and knotweed.
- Research best practices for airblast management that improve efficacy and minimize drift.
- Research best practices for application technology, including spray volume and best efficacy for sucker and weed control.
- Research the efficacy of horticultural oils for insect control.
- Research the potential for use of smart sprayers (sensor-equipped sprayers) with airblast application.

Regulatory actions

- Register horticultural oils for use in both organic and conventionally grown hazelnuts.
- Clarify the method for calculating the number of applications per season with respect to spot spraying.

Education

- Educate growers and pest managers on best practices for using horticultural oils for insect control.
- Educate growers and pest managers on alternatives to pyrethroids for filbertworm and other insect control.
- Educate growers and pest managers on using phenology models for timing of control for filbertworm.
- Educate growers and pest managers on the importance of monitoring, and proper monitoring techniques, for filbertworm management.
- Educate growers and pest managers on best practices for drift management, and effective drift reduction technologies.
- Educate growers and pest managers on best application practices for sucker control that maximize efficacy and minimize risks and losses.

Harvest through postharvest (September–November)

Harvest generally occurs during the month of October but can be slightly earlier or later depending on the weather and cultivar. Leaves are dropping during November, and by the end of November trees are beginning to enter dormancy.

Prior to harvest, during September and early October, nuts have fallen from the tree to the orchard floor. Once a significant number of nuts have fallen, harvest begins. Depending on nut fall and weather, multiple harvests may occur. Nuts are not shaken from trees, as trees would be damaged due to a very thin bark and shallow root system. All commercially grown hazelnuts are harvested mechanically. Harvest is often a two-step operation. First, nuts on the orchard floor are mechanically swept into a windrow between the tree rows. Then a harvesting machine picks up the nuts from the windrow and drops them into a tote box or trailer. The nut harvester also separates out twigs, leaves, and other debris as the nuts are being harvested. The nuts are then transported out of the orchard to a cleaning and drying facility. Newer machines are available which don't require the "windrowing" stage of sweeping the nuts between tree rows.

Major pests managed during this timeframe include brown marmorated stink bug, kernel mold, and bacterial blight. Growers are also managing for nut quality at this time, which includes managing issues such as mud.

Field activities and pest management decisions that occur during harvest through postharvest

- Postharvest lime applications
- Harvesting

<table>
<tr><th>PAMS practice</th><th>Harvest through postharvest pest management activities</th><th>Target pest(s)</th></tr>
<tr><td>Prevention</td><td>None at this time</td><td></td></tr>
<tr><td rowspan="3">Avoidance</td><td>Harvest sooner, before fall rains begin; multiple harvests</td><td>Kernel mold</td></tr>
<tr><td>Processing and drying sooner, and as quickly as possible after harvest</td><td>Kernel mold</td></tr>
<tr><td>Harvesting over a ground cover (helps keep nuts dry)</td><td>Kernel mold</td></tr>
<tr><td>Monitoring</td><td>None at this time</td><td></td></tr>
<tr><td rowspan="2">Suppression</td><td>Shooting birds and (legal-to-shoot) squirrels</td><td>Birds, squirrels</td></tr>
<tr><td>Fungicide applications:
■ Bacillus subtilis (Serenade) (used nonbearing)
■ Copper-based products</td><td>Bacterial blight</td></tr>
</table>

Critical needs for pest management during harvest through postharvest

Research topics

- Research best drying protocols for different varieties to preserve shelf stability.
- Research best practices for postharvest handling to prevent human pathogens.
- Research the biology and best practices for management of kernel mold.
- Develop phenology models to predict harvest timing of different hazelnut cultivars.
- Research products that precipitate/initiate nut fall.

Regulatory actions

- Work to ensure growers have the right to shoot blue birds and Steller's jays without having to fill out and send in reports of their control.

Education

- Educate growers and pest managers regarding good agricultural practices (GAPs) to ensure food safety during harvest and postharvest.
- Educate growers and pest managers on harvest practices that avoid kernel mold.

Photo by Bob Rost, © Oregon State University

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Appendices

Appendix A

Activity Tables for Hazelnuts in Washington and Oregon

Note: An activity may occur at any time during the designated time period but generally not continually during that time period.

Field Activities (other than pest management)

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Boron application to increase nut set			X	X	X							
Cover crop planting	X	X	X	X						X	X	X
Fertilization	X	X	X	X	X	X	X	X	X	X	X	X
Flailing	X	X	X	X	X			X	X		X	X
Harvest									X	X	X	
Irrigation					X	X	X	X	X			
Lime application postharvest									X	X	X	
Mowing			X	X	X							
Orchard floor leveling/management			X	X	X	X	X	X	X			
Pruning	X	X	X	X	X						X	X
Sucker control			X	X	X	X	X	X	X			

Pest Management Activities

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Fungicide application	X	X	X	X	X							
Herbicide application	X	X	X	X	X	X	X	X			X	X
Insecticide application			X	X	X	X	X	X	X			
Moss and lichen management	X	X									X	X
Pheromone dispensers for mating disruption			X	X	X							
Placement and monitoring of traps for filbertworm					X	X	X	X	X			
Pruning for bacterial blight					X	X	X	X	X			
Scouting			X	X	X	X	X	X	X			
Trunk painting			X	X	X							
Vole and squirrel management	X	X									X	X

Appendix B

Seasonal Pest Management for Hazelnuts in Oregon and Washington

Note: X = times when pest-management strategies are applied to control these pests, not all times when pest is present.

Insects and mites	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Aphids (filbert and hazelnut)					X	X	X	X	X			
Borers (Pacific flathead and shothole)					X	X	X	X	X			
Brown marmorated stink bug					X	X	X	X	X			
Bud mite			X	X	X							
Filbert worm (flailing Nov–Feb)	X	X			X	X	X	X	X		X	X
Leafroller			X	X	X							
Leaftier			X	X	X							
Scale			X	X	X							
Spider mite					X	X	X	X	X			
Diseases and viruses	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Bacterial blight	X	X			X	X	X	X	X	X	X	X
Eastern filbert blight	X	X	X	X	X				X	X	X	X
Kernel mold									X	X	X	
Lichen and moss	X	X									X	X
Root rots	X	X									X	X
Weeds	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Annual broadleaves			X	X	X	X	X	X	X		X	X
Perennial broadleaves			X	X	X	X	X	X	X		X	X
Annual grasses			X	X	X	X	X	X	X		X	X
Perennial grasses			X	X	X	X	X	X	X		X	X

Appendix C

Hazelnut Insecticide and Fungicide Risk Management

The letters below represent four categories of nontarget risk potentially affected by pesticide use. If a letter is used, it indicates that mitigation is needed at commonly used application rates in order to reduce risk. Risks were calculated using the risk assessment tool IPM PRiME. This table does not substitute for any mitigations required by the product label.

A = Risks to aquatics: invertebrates and fish **T = Risks to terrestrial wildlife: birds and mammals**
P = Risks to pollinators: risk of hive loss **B = Risks to bystanders:** e.g., a child standing at the edge of the field

"ND" means no data is available for this product. "–" means that risks are not anticipated for this product. Any product highlighted in yellow is classified as a "highly hazardous pesticide" (HHP) by the World Health Organization and the Food and Agriculture Organization of the United Nations. These products may pose significant risks to human health or the environment, and risk reduction measures may not be effective in mitigating these risks. (**Note:** See Appendix E, "Herbicide Usage Table" [page 53] for highly hazardous herbicides in use.)

Pesticides	Risks requiring mitigation	Preplant through planting	Dormancy and pollination	Bud break to shoot elongation	Nut development	Harvest through post harvest	Establishment and nonbearing	Early bearing	Target pest(s)	Comments
Insecticides Products marked with ^ are go-to products; those marked with * are considered critical to the industry.		**If used, average number of applications per crop stage**								
Abamectin (Agri-mek)	A, P			1.5					Bud mite	
Acetamiprid (Assail)	A				1				Aphids	
Alpha-cypermethrin (Fastac)	A, P								Filbertworm	
Azadirachtin (Aza-Direct)	–				2				Aphids	Used by organic growers
Bacterium *Bacillus thuringiensis kurstaki* (Btk)	–				2				Filbertworm, leafroller	
Beta-cyfluthrin (Baythroid)	A, P			1	1				Filbertworm, leaftier	
Beta-cyfluthrin + imidacloprid (Leverage)	A, P			1					Aphids	
Bifenazate (acramite)	–			1					Bud mite	
Bifenthrin (Brigade)	A, P				1				Brown marmorated stink bug, filbertworm	
Chlorantraniliprole (Altacor)	–				1–2				Filbertworm, leafroller	

Hazelnut Insecticide and Fungicide Risk Management *(continued)*

Pesticides	Risks requiring mitigation	Preplant through planting	Dormancy and pollination	Bud break to shoot elongation	Nut development	Harvest through post harvest	Establishment and nonbearing	Early bearing	Target pest(s)	Comments
Insecticides **Products marked with ^ are go-to products; those marked with * are considered critical to the industry.**		**If used, average number of applications per crop stage**								
Chlorpyrifos (Lorsban)	A, T, P, B			1					Brown marmorated stink bug, filbertworm	
Chlorpyrifos + lambda cyhalothrin (Cobalt)	A, T, P, B			1					Brown marmorated stink bug, filbertworm	
Clothianiden (Belay)	A, P									Not used
Cyflumetofen (Nealta)	ND			1					Mites	
Cyfluthrin (Tombstone)	A, P				1				Filbertworm	
Diflubenzuron (Dimilin)	A, T									Not used
Diflubenzuron + lambda-cyhalothrin (DoubleTake)	A, T, P									New product, not much use
E,E-8, 10-dodecadienyl acetate (Isomate FBW ring) [pheromone]	–			1					Filbertworm	Only applied once; lasts whole season
Emamectin benzoate (Proclaim)	A, P									Not used
Esfenvalerate (Asana)*	A, P				1–2				Filbertworm	
Etoxazole (Zeal)	A									Not used
Fenpropathrin (Danitol)	A, T, P									Not used
Fenpyroximate (Fujimite)	A, T									Not used
Flupyradifurone (Sivanto)	ND			1						
Gamma-cyhalothrin (Declare, Proaxis)	A									Not used
Hexythiazox (Savey)	–									Not used
Imidacloprid (Admire Pro, many generics)	A, P			1	1				Aphids, Pacific flatheaded borer	

Hazelnut Insecticide and Fungicide Risk Management *(continued)*

Pesticides	Risks requiring mitigation	Preplant through planting	Dormancy and pollination	Bud break to shoot elongation	Nut development	Harvest through post harvest	Establishment and nonbearing	Early bearing	Target pest(s)	Comments
Insecticides **Products marked with ^ are go-to products; those marked with * are considered critical to the industry.**		**If used, average number of applications per crop stage**								
Lambda-cyhalothrin (Warrior II, generics)	A, P				1				Filbertworm, aphids	
Lambda-cyhalothrin + thiamethoxam (Endigo)	A, P									New product, not much use yet
Methoxyfenozide (Intrepid)	–				1				Filbertworm	
Permethrin (Ambush)	A, T, P									Not used
Pyridaben (Nexter)	A, P									Not used
Pyriproxyfen (Esteem)	–									Not used
Spinetoram (Delegate)	P				1					
Spinosad (Entrust, Success)	P				3				Filbertworm	For organic growers
Spirodiclofen (Envidor)	A		1							
Fungicides		**Number of applications per crop stage** **Note: Total fungicide use within rotation for EFB averages 4 apps/season; sometimes up to 6 are used.**								
Azoxystrobin + difenoconazole (Quadris Top)	A			1–2			1–2	1–2	eastern filbert blight (EFB)	Part of rotation
Azoxystrobin + propiconazole (QuiltXcel, Aframe Plus)	A			1–2			1–2	1–2	EFB	Part of rotation
Bacillus subtilis (Serenade)	–					0–1	1–2	0–1	Bacterial blight	
Chlorothalonil (Bravo Weather Stik, Echo)	A, T			1–2			1–2	1–2	EFB	Part of rotation
Copper hydroxide (Kocide NuCop, Champ)	T					0–1	1–2	0–1	Bacterial blight	

Hazelnut Insecticide and Fungicide Risk Management *(continued)*

Pesticides	Risks requiring mitigation	Preplant through planting	Dormancy and pollination	Bud break to shoot elongation	Nut development	Harvest through post harvest	Establishment and nonbearing	Early bearing	Target pest(s)	Comments
Copper hydroxide + copper oxychloride (Badge X2)	T, P					0–1	1–2	0–1	Bacterial blight	
Cuprous oxide (Nordox 75WG)	P					0–1	1–2	0–1	Bacterial blight	
Copper sulfate (Cuprofix Ultra 40 Disperss)	A					0–1	1–2	0–1	Bacterial blight	
Flutriafol (Topguard)	ND			1–2			1–2	1–2	EFB	Part of rotation
Flutriafol + azoxystrobin (Topguard EQ)	A, ND			1–2			1–2	1–2	EFB	Part of rotation
Fluxapyroxad + pyraclostrobin (Merivon)	A			1–2			1–2	1–2	EFB	Part of rotation
Peroxyacetic Acid (Oxidate)	–					0–1	1–2	0–1	Bacterial blight	Organic approved
Propiconazole (Bumper 41.8EC)	–			1–2			1–2	1–2	EFB	Part of rotation
Propiconazole (Tilt)	–			1–2			1–2	1–2	EFB	Part of rotation
Propiconazole + trifloxystrobin (Stratego)	A			1–2			1–2	1–2	EFB	Part of rotation
Pyraclostrobin (Cabrio EG)	A			1–2			1–2	1–2	EFB	Part of rotation
Trifloxystrobin (Gem 500SC)	A			1–2			1–2	1–2	EFB	Part of rotation
Triflumizole (Procure 480SC)	–			1–2			1–2	1–2	EFB	Part of rotation
Ziram	A, T, P			1–2			1–2	1–2	EFB	New registration, part of rotation
Herbicides	**For herbicide risk classification, see Appendix E, “Herbicide Usage Table,” page 53.**									

Appendix D-1

Efficacy Ratings for INSECT and MITE Management Tools in Hazelnuts

Rating scale: **E** = excellent (90–100% control); **G** = good (80–90% control); **F** = fair (70–80% control); **P** = poor (<70% control); **?** = efficacy unknown in management system—more research needed; ***** = effective but not a stand-alone option

Management tools	Filbert bud mite (rust mite)	Omnivorous leaftier	Obliquebanded leafroller (OBLR) and filbert leafroller	Filbertworm	Filbert aphid, hazelnut aphid	Brown marmorated stink bug	Spider mite	Lecanium scale	Borers	Comments
Registered chemistries										
Abamectin (Agri-mek)	F									Timing is a challenge
Acetamiprid (Assail)					G					
Alpha-cypermethrin (Fastac)				G						
Azadirachtin (Aza-Direct)					F					
Bacterium *Bacillus thuringiensis kurstaki* (Btk)			G							
Beta-cyfluthrin (Baythroid)		E		E						
Beta-cyfluthrin + imidacloprid (Leverage)					E			G		
Bifenazate (acramite)	P									
Bifenthrin (Brigade)				E		E				
Chlorantraniliprole (Altacor)			E	G						
Chlorpyrifos (Lorsban)		E	E						G	Long residual, very effective
Chlorpyrifos + lambda cyhalothrin (Cobalt)		E	E	E		G				
Clothianidin (Belay)										Not used
Cyflumetofen (Nealta)	G						G			
Cyfluthrin (Tombstone)				G	G			G		
Diflubenzuron (Dimilin)										Low use, buffer restrictions
Diflubenzuron + lambda-cyhalothrin (DoubleTake)						G				
E,E-8, 10-dodecadienyl acetate (Isomate FBW ring) [pheromone]				G						
Emamectin benzoate (Proclaim)										Low use
Esfenvalerate (Asana)*			E	E		F				
Etoxazole (Zeal)										Low use
Fenpropathrin (Danitol)										Low use
Fenpyroximate (Fujimite)	G									Low use; probably effective against spider mite

Efficacy Ratings for INSECT and MITE Management Tools in Hazelnuts *(continued)*

Management tools	Filbert bud mite (rust mite)	Omnivorous leaftier	Obliquebanded leafroller (OBLR) and filbert leafroller	Filbertworm	Filbert aphid, hazelnut aphid	Brown marmorated stink bug	Spider mite	Lecanium scale	Borers	Comments
Gamma-cyhalothrin (Declare, Proaxis)				E?						Low use
Hexythiazox (Savey)										Low use
Imidacloprid (Admire Pro, many generics)					E				G	Limited experience with borer control
Lambda-cyhalothrin (Warrior II, generics)			G	G		F				
Lambda-cyhalothrin + thiamethoxam (Endigo)										Low use
Methoxyfenozide (Intrepid)			E	E						Expensive but protects beneficials
Permethrin (Ambush)						G				Low use/experience
Permethrin (Pounce)						G				Low use
Pyridaben (Nexter)	P									
Pyriproxyfen (Esteem)			E	E						Low use, expensive
Spinetoram (Delegate)			E	G						Low use
Spinosad (Entrust, Success)			E	F						
Spirodiclofen (Envidor)	F									
Unregistered/new chemistries										
Micronated sulfur	G									
Flupyradifurone (Sivanto)					E			E		
Horticultural oil	G						G			
Cultural/nonchemical strategies										
Breeding for bud mite resistance	*									
Biological control for aphids, brown marmorated stink bug					*	*				
Filbertworm flailing				*						
Fertilization management					*					
Dust management							*			
Habitat management for filbertworm (extra orchard)				*						
Monitoring nonbearing orchards for filbertworm				*						
Orchard floor management				*						

Appendix D-2

Efficacy Ratings for DISEASE and PATHOGEN Management Tools in Hazelnuts

Rating scale: **E** = excellent (90–100% control); **G** = good (80–90% control); **F** = fair (70–80% control); **P** = poor (< 70% control); **?** = efficacy unknown, more research needed

Management tools	Eastern filbert blight	Bacterial blight	Root rots: *phytophthora* and *armillaria*	Wood decay	Lichen and moss	Trunk cankers and branch dieback (not EFB)	Kernel molds	Comments
Registered chemistries								
Azoxystrobin (Abound)	F	?						
Azoxystrobin + difenoconazole (Quadris Top)	G–E							
Azoxystrobin + propiconazole (Quilt, Aframe Plus)	G							
Bacillus subtilis (Serenade)	P	F–G						
Chlorothalonil (Bravo Weather Stik, Echo)	G–E							
Copper ammonium carbonate (Copper-Count-N)	P	P						Was used; not often used now
Copper hydroxide (Kocide NuCop, Champ)	P	F			F			Expensive
Copper hydroxide + copper oxychloride (Badge X2)	P	F			F			
Copper oxychloride + copper sulfate (C-O-C-S WDG)	P	P–F						Never used
Copper oxide (Nordox 75WG)	P	P–F			F			Low use
Copper sulfate (Cuprofix Ultra 40 Disperss)	P	P–F			F			Not much use
Flutriafol (Topguard)	G							Not much use
Flutriafol + azoxystrobin (Topguard EQ)	G							Not much use
Fluxapyroxad + pyraclostrobin (Merivon)	G							Expensive
Metconazole (Quash)	G	none						Never used
Peroxyacetic Acid (Oxidate)	P	G						Not long lasting
Polyoxin-D (PhD)	F	none						Never used
Propiconazole (Bumper 41.8EC)	G–E							Not used much

Efficacy Ratings for DISEASE and PATHOGEN Management Tools in Hazelnuts *(continued)*

Management tools	Eastern filbert blight	Bacterial blight	Root rots: *phytophthora* and *armillaria*	Wood decay	Lichen and moss	Trunk cankers and branch dieback (not EFB)	Kernel molds	Comments
Propiconazole (Tilt)	G–E							Inexpensive, plant growth regulator
Propiconazole + trifloxystrobin (Stratego)	G–E							Reasonably priced
Pyraclostrobin (Cabrio EG)	G							Reasonably priced
Tebuconazole + sulfur (Unicorn DF)	G	none						Never used
Trifloxystrobin (Flint)	G							Reasonably priced
Triflumizole (Procure 480SC)	F							Expensive
Ziram	E	none						New product; little experience
Cultural/nonchemical strategies								
Burning of prunings	F			?		?		Prior to bud break
Chipping of prunings	F			P		?		Prior to bud break
Cultivar selection	E	?					G	
Early harvest							F–G	
Irrigation of young orchards		G						
Mulching		F						Irrigation is better
Multiple harvests							F–G	
Pruning	P	P		P		?		Must be integrated with other tactics
Shallow planting			G					

Appendix D-3

Efficacy Ratings for WEED Management Tools in Hazelnuts

Rating scale: E = excellent (90–100% control); **G** = good (80–90% control); **F** = fair (70–80% control);
P = poor (<70% control); **?** = efficacy unknown—more research needed

Note**:** Weed size or stage of growth is an important consideration with most postemergence herbicides.

In the “Pre/Post” column, **Pre** = soil-active against preemerged weeds; **Post** = foliar-active against emerged weeds.

Management tools	PRE/ POST	Annual broadleaves (knotweed, fluvelin, groundsel)	Perennial broadleaves (field bindweed, Canada thistle, blackberry)	Annual grasses (barnyard grass, crabgrass, ryegrass, bluegrass, foxtail)	Perennial grasses (quackgrass)	Horsetail	Wild carrot	Nutsedge	Wild garlic	Comments
Registered chemistries										
2,4-D (Saber)	POST	P	P			P	P		P	Used for sucker control or tank mixed
Acetic acid (Weed Pharm)	POST									Organic approved, little experience with this product
Carfentrazone (Aim)	POST	P	F			P	P		P	Better on other species
Clethodim (Select Max)	POST			E	F					Resistance issues in grasses
Dichlobenil (Casoron)										Never used
Diquat (Reglone)										Never used
Diuron (Karmex)	PRE	G		G	?					Resistance issues in grasses
Flazasulfuron (Mission)	PRE/ POST									New product, expensive, limited use
Fluazifop (Fusilade)	POST									Not commonly used; nonbearing
Flumioxazin (Chateau)	PRE	P			?	F			?	Not commonly used
Glufosinate (Rely)	POST	E	F	G	P	P	P	P	P	Resistance issues in grasses
Glyphosate (Roundup)	POST	E	E	E	E	F	G	P	P	Resistance issues in grasses
Halosulfuron (Sandea)	POST							E		Costly, narrow spectrum of weeds controlled
Indaziflam (Alion)	PRE	E	P	E	P	?	P		P	Costly
Isoxaben (Trellis, Gallery)	PRE									Costly, never used
Napropramide (Devrinol)	PRE									Never used

Efficacy Ratings for WEED Management Tools in Hazelnuts *(continued)*

Management tools	PRE/ POST	Annual broadleaves (knotweed, fluvelin, groundsel)	Perennial broadleaves (field bindweed, Canada thistle, blackberry)	Annual grasses (barnyard grass, crabgrass, ryegrass, bluegrass, foxtail)	Perennial grasses (quackgrass)	Horsetail	Wild carrot	Nutsedge	Wild garlic	Comments
Norflurazon (Solicam)	PRE									Never used
Oryzalin (Surflan)	PRE			G						Safe on new trees
Oxyfluorfen (Goal Tender)	PRE/ POST	G		G						Less expensive option
Paraquat (Gramoxone)	POST	E	P	G	P	P	P	P	P	Used often, resistance issues with grasses
Pendimethalin (Prowl)	PRE	G		G	P	?				Used on young trees
Pyraflufen (Venue)	POST									New product; little experience
Rimsulfuron (Matrix)	PRE/ POST									Expensive, used in tank mix
Saflufenacil (Treevix)	POST									New product; little experience
Sethoxydim (Poast)	POST			E	?					Resistance issues with grasses
Simazine (Princep)	PRE	G		F	?	?	P	P	P	Inexpensive
Sulfentrazone (Zeus)	PRE	G	F			P	P	G	G	New label
Triclopyr (Crossbow)		G	G				G			
Trifluralin (Treflan)										Not commonly used; ornamental
Trifluralin + isozaben + oxyfluorfen (Showcase)										Not commonly used; ornamental
Unregistered/new chemistries										
Cultural/nonchemical strategies										
Flail mowing										Used but not a stand-alone tool
Leveling (tillage)										Used but not a stand-alone tool

Appendix E

Herbicide Usage Table

The following table includes herbicides used, their associated risk classification (described below), their herbicide mechanism of action group number according to the Weed Science Society of America (WSSA), and information regarding timing of use.

For the “Risks Requiring Mitigation” column, the letters indicated represent four categories of non-target risk potentially affected by pesticide use. If a letter appears, it indicates that mitigation is needed at commonly used application rates in order to reduce risk.

A = Risks to aquatics: invertebrates and fish **T** = Risks to terrestrial wildlife: birds and mammals
P = Risks to pollinators: risk of hive loss **B** = Risks to bystanders: e.g., a child standing at the edge of the field
“ND” means no data is available for this product. “–“ means that risks are not anticipated for this product.

Risks were calculated using the risk assessment tool IPM PRiME. This table does not substitute for any mitigations required by the product label. Any product highlighted in yellow is classified as a “highly hazardous pesticide” (HHP) by the World Health Organization and the Food and Agriculture Organization of the United Nations. These products may pose significant risks to human health or the environment, and risk reduction measures may not be effective in mitigating these risks.

Note: In “Activity” column, Pre = soil-active against preemerged weeds; Post = foliar-active against emerged weeds.

Herbicide	Risks requiring mitigation	WSSA group	Activity	Remarks	Minimum age		Crop age when product is used						Time of year (number of applications expected in a given season)			
							0 leaf	1st leaf	2nd leaf	3rd leaf	4th leaf	Bearing	Fall	Winter	Spring	Summer
2,4-D (Saber)	–	4	POST	bearing	12 months		X	X	X	X	X	X			1	1–4
Acetic acid (Weed Pharm)	–		POST	bearing												
Caprylic acid (Suppress EC)	ND		POST						X	X	X	X				3–4
Carfentrazone (Aim)	–	14	POST	bearing												
Clethodim (Select Max)	–	1	POST	non-bearing	planting	new plants	X	X								2
Dichlobenil (Casoron)	T	20	PRE	bearing	planting											
Diquat (Reglone)	T	22	POST	non-bearing	planting											

Herbicide Usage Table *(continued)*

Herbicide	Risks requiring mitigation	WSSA group	Activity	Remarks	Minimum age		Crop age when product is used						Time of year (number of applications expected in a given season)			
							0 leaf	1st leaf	2nd leaf	3rd leaf	4th leaf	Bearing	Fall	Winter	Spring	Summer
Diuron (Karmex)	T	7	PRE	bearing	12 months			X				X			1	1
Fluazifop (Fusilade)	–	1	POST	non-bearing												
Flumioxazin (Chateau)	ND	14	PRE/ POST	bearing	12 months											
Glufosinate (Rely)		10	POST	bearing		new plants	X	X	X	X	X	X			1	2–4
Glyphosate (Roundup)	T	9	POST	bearing		new plants	X	X	X	X	X	X	1		1	1–3
Halosulfuron (Sandea)	–	2	POST	bearing	12 months											
Indaziflam (Alion)	–	29	PRE	bearing	12 months			X	X	X	X	X			X	
Isoxaben (Trellis, Gallery)	T	21	PRE	bearing		new plants										
Napropamide (Devrinol)	T	3	PRE	bearing	planting	new plants										
Norflurazon (Solicam)	A, T	12	PRE	bearing	6 months											
Oryzalin (Surflan)	A, T	3	PRE	bearing	planting	new plants										
Oxyfluorfen (Goal Tender)	A, T	14	PRE/ POST	bearing	planting	new plants	X	X	X							
Paraquat (Gramoxone)		22	POST	bearing			X	X	X	X	X	X			1	2–3
Pendimethalin (Prowl)	T	3	PRE	bearing	planting	new plants	X	X	X	X	X				1	1
Pyraflufen (Venue)	–	14	POST	bearing	planting	new plants										

Herbicide Usage Table *(continued)*

Rimsulfuron (Matrix)	–	2	PRE/ POST	bearing	12 months											
Saflufenacil (Treevix)	–	14	POST	bearing	9 months											
Simazine (Princep)	T	5	PRE	bearing	12 months							X			1	1
Sulfentrazone (Zeus)	T	14	PRE	bearing	12 months											
Trifluralin (Treflan)	T	3	PRE	non-bearing	planting	new plants										
Sethoxydim (Poast)	–	1	POST	bearing												

Appendix F

Using PAMS Terminology

This system of terminology for IPM was developed for use by U.S. Federal agencies seeking to support adoption of IPM by farmers. The table below summarizes common tactics used in agricultural IPM using a "Prevention, Avoidance, Monitoring, Suppression" (PAMS) classification. We also define (in ***italics***) the ecological purpose that lies behind a particular practice. The PAMS tables throughout the text provide a simple basis for surveying practices that are used at different crop growth stages in terms of their contribution to a comprehensive IPM program.

P PREVENTION

Prevent introduction to the farm
- Pest-free seeds, transplants

Prevent reservoirs on the farm
- Sanitation procedures
- Eliminate alternative hosts
- Eliminate favorable sites in and off crop

Prevent pest spread between fields on the farm
- Cleaning equipment between fields

Prevent pests developing within fields on the farm
- Irrigation scheduling to prevent disease development
- Prevent weed reproduction
- Prevent pest-susceptible perennial crops by avoiding high-risk locations

M MONITORING

Collect pests
- Scouting and survey approaches
- Traps

Identify pests
- Use of identification guides, diagnostic tools and diagnostic laboratories

Identify periods or locations of high pest risk
- Use weather-based pest-development and risk models
- Use soil and plant nutrient testing

Determine status and trends in pest risks and classify pest severity
- Maintain pest records over time for each field

Minimize pest risks over time
- Plan an appropriate PAMS IPM strategy, based upon pest status and trends

Determine interventions based upon risks and economics
- Use of decision-support tools, economic thresholds

A AVOIDANCE

Avoid host crops for the pest
- Crop rotation

Avoid pest-susceptible crops
- Choose genetically resistant cultivars
- Choose cultivars with growth and harvest dates that avoid the pest
- Place annual crops away from high-risk sites for pest development (even parts of a field)

Avoid crop being the most attractive host
- Trap cropping
- Use of pheromones
- Use crop nutrition to promote rapid crop development

Avoid making the crop excessively nutritious
- Use nutrition to promote rapid crop development
- Avoid excessive nutrients that benefit the pest

Avoid practices that increase the potential for pest losses
- Narrow row spacing
- Optimized in-row plant populations
- No-till or strip till

S SUPPRESSION

CULTURAL	***Outcompete the pest with other plants*** • Cover crops ***Suppress pest growth*** • Mulches ***Suppress pest with chemicals from crops or other plantings*** • Bio-fumigant crops
PHYSICAL	***Physically injure pest or disrupt pest growth*** • Cultivation • Mowing • Flaming • Temperature management • Exclusion devices ***Physically remove pests*** • Mass trapping • Hand weeding
BIOLOGICAL	***Suppress pest reproduction*** • Pheromones ***Increase pest mortality from predators, parasites, and pathogens*** • Conservation biological control • Inundative release and classical biological control • Use of pest antagonists
CHEMICAL	***Use of least-risk, highest-efficacy pesticides*** • Use economic thresholds to determine that pesticide use is economically justified • Use pesticides as a last resort, as part of a PAMS IPM strategy

Table: Paul Jepson, IPPC Oregon State University, paul.jepson@oregonstate.edu

Appendix G

Pesticide Risk Classification

Paul Jepson, Oregon State University

The pesticide risk analysis is based on the Oregon State University Integrated Plant Protection Center's state-of-the-science risk assessment tool IPM PRiME, a risk model that identifies moderate to high (10% or greater) risk (Jepson et al., 2014, Sustainable Agriculture Network 2017). We analyzed a total of 800 pesticides, and 168 of these posed risks to human workers and bystanders, aquatic life, wildlife, and pollinators. The analysis is intended to provide guidance that is supplementary to the label, which is the primary source of risk management information and mandatory practices.

1. Risk to aquatic life

Pesticides qualified for this risk category if one or more IPM PRiME aquatic risk models (aquatic algae, aquatic invertebrates, or fish chronic risk) exhibited high risk at a typical application rate.

2. Risk to terrestrial wildlife

Pesticides qualified for this risk category if one or more IPM PRiME terrestrial risk models (avian reproductive, avian acute, or small mammal risk) exhibited high risk at a typical application rate.

3. Risk to pollinators

Pesticides were selected based on a widely-used hazard quotient (HQ) resulting of pesticide application rate in g a.i./ha, and contact LD50 for the honey bee (*Apis mellifera*). Values of HQ < 50 have been validated as low risk in the European Union, and monitoring indicates that products with an HQ > 2,500 are associated with a high risk of hive loss. The HQ value used by IPPC is >350, corresponding to a 15% risk of hive loss. The quotient includes a correction for systemic pesticides, where risks to bees are amplified.

4. Inhalation risk

Inhalation risk to bystanders was calculated using the ipmPRiME model for inhalation toxicity (Jepson et al., 2014) calculated on the basis of child exposure and susceptibility. This index is protective for workers who may enter fields during or after application, and also bystanders.