Pest Management Strategic Plan

for

Hazelnuts

in

Oregon and Washington

Summary of a workshop held on
November 29, 2006
Aurora, Oregon

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This project was sponsored by the Western Integrated Pest Management Center, which is funded by the United States Department of Agriculture, Cooperative State Research, Education, and Extension Service.

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Summary of Critical Needs

(Pest-specific and crop-stage-specific aspects of these needs, as well as additional needs, are listed and discussed throughout the body of the document.)

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.

- 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.

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

- 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.

- 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. It is believed that some of the damage attributed to the filbertworm may be caused by the filbert weevil.

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.

- Retain the registration of chlorpyrifos (Lorsban and other brands), 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.

- 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.

- 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.

- 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.

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.

- 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.

- 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.

- 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.

Introduction

The Environmental Protection Agency (EPA) has completed the risk assessment required under the Food Quality Protection Act of 1996 (FQPA) and is continuing its reregistration process. With the advent of the FQPA and the subsequent risk assessments, several pesticides have been cancelled or now have reduced or more restrictive label uses.

In addition to the risk assessments and reregistration efforts of the EPA, the Endangered Species Act (ESA) may also impact the availability or restrict the use of certain pesticides. The ESA requires that any federal agency, including EPA, taking an action that may affect threatened or endangered species must consult with either the National Oceanic and Atmospheric Administration (NOAA-Fisheries) or the U.S. Fish and Wildlife Service, as appropriate. Lawsuits have been filed against EPA alleging the Agency failed to complete this consultation process. One lawsuit resulted in the establishment of buffers for applications of certain pesticides around salmon-supporting waters in Washington, Oregon, and California. Threatened and endangered species other than salmon are located throughout hazelnut growing regions, and there are likely to be further requirements for the protection of these species, whether they are court-ordered or result from the consultation process.

Because buffers are not in general use, no one knows their impact on agro-ecosystems or the pest complex. Whether planted to crops, planted to vegetation that is habitat for beneficial insects, abandoned to weeds, or managed for other values, buffers have the potential to play either a positive or a negative role in the pest complex in and adjacent to hazelnut orchards. If pest management needs in buffer zones are not addressed or understood, growers may simply resort to cultivation to keep these areas free of weeds. Improper cultivation practices may lead to increased sediment loads in streams.

Growers and commodity groups recognize the importance of developing long-term strategies to address pest management needs. These strategies may include identifying critical pesticide uses; retaining critical uses; researching pest management methods with an emphasis on economically viable solutions; and understanding the impacts of pesticide cumulative risk. The total effects of FQPA and ESA have yet to be determined. Clearly, however, new pest management strategies will be required in the hazelnut industry.

Process for this Pest Management Strategic Plan

In a proactive effort to identify pest management priorities and lay a foundation for future strategies, hazelnut growers, commodity group representatives, pest control advisors, regulators, environmentalists, university specialists, and other technical experts from Oregon and Washington formed a work group and assembled this document. Members of the group met for a day in November, 2006, in Aurora, Oregon, where they discussed the FQPA and possible pesticide regulatory actions and drafted a document containing critical needs, general conclusions, activity timetables, and efficacy ratings of various management tools for specific pests in hazelnut production. The resulting document was reviewed by the work group, including additional people who were not present at the meeting. The final result, this document, is a comprehensive strategic plan that addresses many pest-specific critical needs for the hazelnut industry in Oregon and Washington.

The document begins with an overview of hazelnut production, followed by discussion of critical production aspects of this crop, including the basics of Integrated Pest Management (IPM) in hazelnuts. The remainder of the document is an analysis of pest pressures during the production of hazelnuts, organized by crop life stage. Key control measures and their alternatives (current and potential) are discussed.

Each pest is mentioned in the crop stage in which IPM, cultural controls (including resistant varieties), and/or chemical controls (including pre-plant pesticide treatments) are utilized, or when damage from that pest occurs. Descriptions of the biology and life cycle of each pest are described in detail under the crop stage in which they are present. Within each major pest grouping (insects, diseases, and weeds), individual pests are presented in alphabetical order, not in order of importance.

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

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., introduced in the mid-1800s, that is grown for commercial nut production in Oregon and Washington. Some cultivars first developed in the early 1900s are still being grown today. While the name most people nationally and internationally use for these nuts is "hazelnuts," some growers and local residents in the Pacific Northwest refer to them as "filberts." Several of the pests associated with hazelnuts, such as "filbertworm" and "eastern filbert blight," still carry this moniker.

The hazelnut grows naturally as a bush or multi-stemmed shrubby tree, but in the Pacific Northwest hazelnuts are grown as a single-trunk tree. Suckers growing at the base of the tree that would normally create a shrubby tree are removed throughout the year to help create and maintain a single-stemmed tree. Trees can attain a height of 40+ feet when planted in good soil and managed with proper pruning, fertilization, and pest control practices.

The soils and climate in the western regions of Oregon and Washington are well suited to hazelnut production. Hazelnuts grow best on deep, river-bottom soils but also grow well on a wide variety of other soil types. While the hazelnut tree itself is quite hardy, satisfactory crops are produced only under moderate climatic conditions. Female hazelnut flower clusters begin to form on current season's growth, usually in mid-summer. 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 mid-summer, 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 to15°F) can damage male and female flowers and reduce crop yield, but the mild winter weather common in western Oregon and Washington is 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.'

Currently about 60% of Pacific Northwest hazelnut orchards are planted with the cultivar 'Barcelona,' which is an older cultivar with many good attributes, such as

- a vigorous and upright growth habit
- good yields
- round-shaped nuts that are medium to large in size, have excellent flavor, and are suitable for both the kernel market and the in-shell market

Other common cultivars include Ennis, Hall's Giant, and Willamette. Barcelona does, however, have some undesirable characteristics, the most important of which is that it is only moderately resistant to eastern filbert blight disease. The Oregon State University hazelnut breeding program is currently developing cultivars that are an improvement on Barcelona. These have many desirable characteristics, such as heavy annual production, fewer blanks and kernel defects, and resistance to eastern filbert blight. Recent cultivar releases from the breeding program, such as Santiam, Lewis, Clark, and Sacajawea, have high resistance to eastern filbert blight. Cultivars used specifically as pollinizer trees include Delta, Epsilon, Gamma, and Zeta, which were recently released from the breeding program and are resistant to eastern filbert blight. New orchards are being planted with the new and improved cultivars, and in older orchards pollinizer trees are being replaced with the new disease-resistant cultivars.

Hazelnut trees do not produce a commercially harvestable crop until the third year in the ground, and they reach full production only after 10 to 12 years. If they are well-managed, hazelnut trees remain productive for 40 years or more. 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 six years and older respond to foliar- or soil-applied boron, which increases nut set.

Virtually all the hazelnuts produced commercially in the United States are grown in the Pacific Northwest, which represents about three to five percent of the world's hazelnut production. There is a national and international demand for organic hazelnuts. Although there is a small amount of organic acreage in Oregon and Washington, the primary challenge has been to economically control filbertworm. This has limited the expansion of organic acreage. The Pacific

Northwest hazelnut industry is interested in developing a cost-effective organic hazelnut production system.

About 99% of U.S. production occurs in the Willamette Valley of Oregon, and the remaining 1% occurs in Washington. Production from mature orchards ranges from less than 1,000 pounds to more than 3,000 pounds of dry nuts per acre. A well-managed orchard produces an average of 2,300 pounds of dry nuts per acre. The value of the nut crop varies from year to year. The price per pound that Pacific Northwest growers receive is strongly influenced by worldwide hazelnut prices. In the past five years, the price per pound received by Oregon and Washington growers has ranged from $0.35 to $1.15. In 2005, Oregon and Washington growers produced about 27,890 tons of nuts on 28,600 acres, with a farm-gate value of $62.5 million.

In Oregon there are about 28,000 bearing acres of hazelnuts in production. Although Douglas County in southern Oregon has about 100 acres, the majority of the production takes place in the Willamette Valley in western Oregon, located between the Cascade Mountains and the Coast Range. Yamhill County has the most acreage (6,350 acres), followed by other Willamette Valley counties: Marion, Washington, Clackamas, Lane, Polk, Linn, Benton, and Multnomah.

Commercial hazelnut production in Washington is relatively small (about 300 bearing acres) and 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 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.

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 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. 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 either shelled or in the shell and are used locally or nationally or shipped to overseas markets.

Integrated Pest Management Strategies in Hazelnut Production

The hazelnut industry relies heavily on Integrated Pest Management (IPM) to control insect, disease, and weed pests that are found in hazelnut orchards and to reduce 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 three decades.

Advances in insect pest 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 bio-control program, because the elimination of aphicides improves survival of predators and parasitoids that attack leafrollers and filbertworm.

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 bio-control success of *Trioxys 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 approach in 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.

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. 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 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.

Pests and Management Options by Crop Stage

PRE-PLANT AND PLANTING

Pre-plant 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.

The site for a hazelnut orchard is carefully considered prior to planting. The soil is prepared to receive hazelnut trees that will remain in the ground for many years. Perennial weeds are treated weeks or months before the planting date. 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. Planting generally occurs in the spring, but orchards are sometimes planted in the fall. Mature trees can reach a height of 40+ feet. Tree and row spacing varies depending on the cultivar planted and the soil type.

Since trees don't yield a commercially harvestable crop of nuts until the third 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 near full production) are options to speed economic returns while the orchard is maturing.

Orchard sites are generally not fumigated prior to planting. Weeds are controlled prior to and at planting, but there are no insects that are treated at this time. Trees are treated prior to or after planting for disease control, particularly for bacterial blight, which causes damage mostly to young trees. Nematodes are not presently recognized as a problem in hazelnut production.

Field activities that may occur during this period:

- Testing soil for nutrients and pH.
- Adding lime, if necessary, prior to disking (add if pH is < 5.6).
- Applying granular potassium fertilizer prior to disking (B and Zn also) if needed.
- Herbicide application for perennial weed control weeks or months prior to planting.
- Subsoiling or ripping to open hardpan.
- Plowing, disking, and cultivating soil.

- Rolling and leveling the soil.
- Planting trees by hand or machine (in spring or fall).
- Pruning tree tops after planting.
- Applying granular fertilizer (nitrogen and potassium) around tree immediately after planting (in a band in subsequent years).
- Irrigating after planting.
- After planting, painting tree trunk with white latex paint or installing tree guards to help prevent sun scald later in the season and for herbicide protection.
- Applying pre-emergence herbicide to tree row after planting.
- Rodent and other vertebrate control, as needed.

INSECTS

No insect management is practiced at this time.

DISEASES

The widespread and devastating disease, eastern filbert blight (discussed later in the section "Bud Break"), requires an integrated approach to management. A fungicide application may be made after planting. However, one of the major methods contributing to control is to plant cultivars that are less susceptible to the disease (such as Santiam, Lewis, Clark, and Sacajawea) and to replace susceptible pollinizer trees with those that are resistant (such as Delta, Epsilon, Gamma, and Zeta). Cultivars and pollinizers need to be compatible with one another. The hazelnut breeding program at Oregon State University is continuing to develop and evaluate new cultivars that will be released to commercial growers and the general public as they become available.

For control of bacterial blight, copper products may be applied to newly planted trees after planting. Bacterial blight and its management are discussed in more detail later in the "Nut Maturation" section of this document.

WEEDS

The spectrum of weed species that can be found growing in hazelnut-growing areas varies depending upon soil type and microclimate conditions. Nevertheless, weed management prior to establishing a new orchard is always a consideration. Hard-to-control perennial weeds such as blackberry, morningglory, dandelion, and thistle are often controlled with a systemic herbicide prior to plowing the soil in preparation for establishing the orchard. Certain herbicides are allowed prior to planting that are not allowed after

planting or in a bearing orchard. Whether an herbicide is allowed in bearing or non-bearing orchards, the choice of an herbicide is based on crop and applicator safety. Growers 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. It is recommended that any cracks or crevices around the tree be filled and sawdust be applied around the base of the tree to further minimize risk of herbicide injury. When using a foliar-active systemic herbicide such as glyphosate for weed control around newly planted trees, it is advisable to avoid herbicide contact with the tree. The tender tissue can absorb the herbicide into the tree and cause damage. Tree guards are used to protect trees from herbicide drift.

Weed control is important because it helps reduce competition for water and nutrients in young trees. Controlling weeds also assists in managing rodent pest populations by eliminating or reducing rodent habitat.

Chemical control:

Pre-plant/site preparation (foliage-active):

- 2,4-D amine (Saber and other brands). Broadleaf weeds. Label restrictions can sometimes limit usefulness, as there is a waiting period before trees can be planted.
- Clethodim (Select). Grasses only. Seldom used because it is expensive, but sometimes necessary for resistance management.
- Fluazifop-P-butyl (Fusilade). Grasses only. Seldom used because it is expensive, but sometimes necessary for resistance management.
- Glyphosate (Roundup and other brands). Systemic. Commonly used. Effective, and it controls both broadleaf and grass weeds.
- Paraquat (Gramoxone and other brands). Contact. Commonly used. Effective, and it controls both broadleaf and grass weeds.
- Sethoxydim (Poast). Grasses only. Seldom used because it is expensive, but sometimes necessary for resistance management.

Post-plant (soil-active):

Many soil-active herbicides are registered for use in hazelnuts (see "Bud Break" section of this document), but only the following are considered safe to use on newly planted trees and trees less than one year old.

- Napropamide (Devrinol). Safe and commonly used on newly planted trees.
- Oryzalin (Surflan). Safe on newly planted trees and commonly used.

- Oxyfluorfen (Goal). Safe on newly planted trees and commonly used.
- Pendimethalin (Prowl H_2O). Safe on newly planted trees. A new registration. Not much grower experience yet.

Post-plant (*foliage-active)*:

- 2,4-D amine (Saber and other brands). Broadleaf weeds. Commonly used.
- Carfentrazone-ethyl (Aim). Broadleaf weeds. Contact.
- Clethodim (Select). Grasses only.
- Fluazifop-P-butyl (Fusilade). Grasses only.
- Flumioxazin (Chateau). Trees must be established at least one year; otherwise, tree damage may occur.
- Glufosinate-ammonium (Rely).
- Glyphosate (Roundup and other brands).
- Oxyfluorfen (Goal). Works well. Commonly used.
- Paraquat (Gramoxone). Commonly used.
- Sethoxydim (Poast). Grasses only.

Biological control:

- None.

Cultural control:

Pre-plant:

- None.

Post-plant:

- Mulch (such as sawdust, compost, or straw) applied around the tree. However, organic mulches can invite rodents.
- Mowing.

Critical Needs for Weed Management in Hazelnuts: Pre-Plant and Planting

Research:

- Identify and test new pre-emergence herbicide chemistries that are cost-effective and that would be useful for rotation with currently registered herbicides to reduce likelihood of resistance or weed shifts.
- Identify and test herbicides that can effectively control field bindweed, horsetail, wild garlic, clovers, and morningglory.

Regulatory:

- Reduce regulations for pesticide record keeping.

- Ensure that hazelnuts are included on new pesticide labels whenever almonds and pecans are registered (EPA Crop Group 14: Tree Nuts).

Education:

- Educate growers, especially new growers, about weed identification and current weed management practices.
- Communicate with and educate EPA and pesticide manufacturers about the need to include hazelnuts on pesticide labels when almonds and pecans (the representative crops of EPA Crop Group 14: Tree Nuts) obtain a registration.

ESTABLISHMENT and NON-BEARING ORCHARDS

Young hazelnut trees do not produce enough nuts for a commercial harvest for the first two years after planting. Full production is not realized until trees have been in the ground for about 10 to12 years. A very small crop is harvested in the third year, and yield increases every year thereafter until the trees reach full production. The period between planting and the time when there is a harvestable commercial crop is known within the hazelnut industry as "establishment." Weed, disease, and insect pests are present in these young non-bearing orchards, but diseases and insects that are specific to flowers or nuts may not be treated at this time. Certain pests, such as the omnivorous leaftier and bacterial blight disease, are problematic only in orchards with young trees. Management of these pests is generally not needed as the trees mature. Certain chemical products that are allowed only in non-bearing orchards will be included as pest management options within the remainder of this document and will be noted as such.

The remainder of this document follows the crop stages of an established, bearing orchard and begins with dormancy. Pest management will be discussed, as appropriate, for both bearing and non-bearing orchards.

DORMANCY

(December, January, February)

As the days get shorter and the weather gets cooler in the fall, hazelnut trees drop their leaves and go into dormancy. Male and female flowers are present

during dormancy, and pollination, with the aid of wind, occurs during dormancy. The ovule is not fertilized until later in the season when nut development occurs. No pest management occurs during dormancy except that branches with evidence of eastern filbert blight are pruned out and destroyed. Moss and lichen are controlled at this time with copper and/or lime sulfur products. 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 that may occur during this period:

- Pruning
- Mowing or chopping brush from prunings
- Scouting for eastern filbert blight
- Destroying (burning) prunings that contain eastern filbert blight
- Fertilization (granular potassium or lime)
- Replanting (if necessary)

Critical Needs for Pest Management in Hazelnuts: Dormancy

Research:

- Continue research for eastern filbert blight control and investigate the relationship between how prunings are treated and incidence of the disease.
- Investigate whether hydrated lime is useful for control of eastern filbert blight.

Regulatory:

- Reduce regulations for pesticide record keeping.
- Ensure that hazelnuts are included on new pesticide labels whenever almonds and pecans are registered (EPA Crop Group 14: Tree Nuts).

Education:

- Educate growers about the importance of scouting for eastern filbert blight, and teach them the scouting skills. Dormancy is a good time to scout, since without foliage on the tree it is easier to see the cankers on the branches.
- Communicate with and educate EPA and pesticide manufacturers about the need to include hazelnuts on pesticide labels when almonds and

pecans (the representative crops of EPA Crop Group 14: Tree Nuts) obtain a registration.
- 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.

BUD BREAK TO FULLY FORMED LEAVES

(March, April, May, and June)

This crop stage begins with bud break in early spring, continues during the spring as leaves unfurl and become fully formed, and ends at about the end of June when nut maturation begins. 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.

Field activities that may occur during this period:

- Scouting (insects, diseases, weeds)
- Fungicide application
- Insecticide application
- Herbicide application (in tree row)
- Herbicide application (broadleaf weed control in row middles)
- Replanting, if necessary
- Fertilization (foliar and soil applied)
- Application of foliar boron fertilizer in mid-May
- Cleaning up winter prunings (chop up or remove), if not already done
- Pruning (finish if not completed during dormancy)
- Painting tree trunk with white latex paint or installing tree guards to help prevent sun scald later in the season and for herbicide protection on young trees (1 to 3 years old)
- Mowing (flail) weeds, as needed
- Sucker removal (chemical or mechanical)

INSECTS

Following are specific control options for specific insect pests that are problematic between bud break and fully formed leaves (up to the beginning of nut maturation). However, it should be noted that many insect pests mentioned below are controlled with just one or two pesticide applications. The goal of the hazelnut pest manager is to use as few chemical sprays as possible to ensure

protection of the naturally occurring beneficial insects that are found in most hazelnut orchards. When pesticide sprays are required they are carefully timed so that control of multiple pests can be achieved.

Aphids

Filbert Aphid (*Myzocallis coryli*). The filbert aphid is the most common aphid found in hazelnut orchards. Aphids feed on any green tissue, and this can reduce plant vigor, the percent of nut fill, and the size of nuts. In addition, the honeydew that is produced by aphids causes a black, sooty fungal mold that can reduce the photosynthetic capacity of the leaves. Aphids appear at bud break and can be problematic throughout the growing season. Aphids are more difficult to control as the season progresses, because as the tree canopy fills out, spray penetration is more difficult. Scouting (examination of terminal branches and leaves) and an established action threshold help growers determine if treatment for aphids is warranted.

A small Braconid wasp, *Trioxys pallidus*, was released in many Oregon hazelnut orchards in the early 1980s and has naturalized throughout the hazelnut-growing regions of Oregon and Washington. Today nearly every hazelnut orchard shows signs of this parasitic wasp that, if undisturbed, helps keep the aphid population in check. Wasp eggs may overwinter on fallen leaves on the ground, so growers delay flail mowing in early spring in order to protect the eggs and allow them to hatch.

These aphids overwinter as eggs on twigs and branches and begin hatching in early spring. Egg hatch continues for three to four weeks. Young aphids molt four times and then become adults that give birth to young aphids without sexual reproduction. As many as ten generations of aphids can be produced in a growing season. The populations usually decline during the heat of the summer, but in the fall winged forms are produced that lay the overwintering eggs. The adults are small to medium in size and are a very pale greenish-white in color.

Large Hazel Aphid (*Corylobium avellanae*). A newly invasive aphid pest, the large hazel aphid, which is also known as the hazelnut aphid, was first reported in Oregon in 2003 and has rapidly spread into many of the areas where hazelnuts are grown. It is believed that the large hazel aphid now comprises about half of the total aphid population found in hazelnut orchards. The large hazel aphid is larger and darker green than the filbert aphid. This new aphid is believed to have a life cycle similar to the filbert aphid; both aphid species can be found on

hazelnut trees at the same time. The parasitic wasp, *Trioxys pallidus*, which helps reduce populations of the filbert aphid does not appear to parasitize the large hazel aphid. Since this is a new pest, management strategies have not been established. It is assumed that chemical controls for the large hazel aphid would be the same as those for the filbert aphid.

Chemical control:

- Azadirachtin (Neemix and other brands). Not very efficacious but useful for organic growers.
- Carbaryl (Sevin). Not used. Harsh on beneficials. It is believed to actually increase aphid populations.
- Chlorpyrifos (Lorsban and other brands). Very effective even at low rates. However, in order to protect *Trioxys* wasps and other beneficial insects that help control the aphid population, it is seldom used.
- Diazinon. Good efficacy. Use allowed on a supplemental label for Platte 500-AG
- Endosulfan (Thiodan, Thionex). Not used much. It is harsh on beneficials and earthworms.
- Imidacloprid (Admire, Provado, and other brands). An effective aphicide, but rarely used because of expense.

Biological control:

- Protect natural predators, especially the wasp, *Trioxys pallidus.*

Cultural control:

- Delay flail mowing in early spring to allow *Trioxys pallidus* wasp eggs to hatch.

Filbert Bud Mite (*Phytocoptella avellanae*)

The filbert bud mite is a very small eriophyid mite that feeds on and within leaf and flower buds and catkins (male flowers). Feeding causes buds to swell to a larger-than-normal size (hence the nickname "big bud mite"), and infested buds do not produce nuts. *Cecidophyopsis vermiformis* is another eriophyid mite also found in hazelnut orchards. *Cecidophyopsis vermiformis* feed in the enlarged buds created by the filbert bud mite; while their feeding does not cause big bud symptoms, it does cause further damage to the bud and, subsequently, yield loss. Mite activity can be monitored by placing a sticky substance (Tanglefoot or sticky tape) on twigs above and below buds that have evidence of mite infestation. Best control is achieved by applying treatments in the early spring

when adult mites become active and are moving about the tree. Susceptibility to bud mite infestation is cultivar-specific. A rating system is used to quantify the degree of susceptibility of cultivars. (See Table 2, page 5 of "Growing Hazelnuts in the Pacific Northwest," Oregon State University Extension publication #EC 1219). The susceptibility of genotypes is assessed in the Oregon State University hazelnut breeding program, and genotypes with high degrees of susceptibility are eliminated from further evaluation.

Chemical control:

- Calcium polysulfide (Lime sulfur, Sulforix, and other brands). Effective. The Sulforix formulation has given growers better results and is the most popular product used.
- Endosulfan (Thiodan and other brands). Not used. Harsh on beneficials.
- Pyridaben (Nexter, Pyramite). Not widely used. It is a newer registration. Growers lack experience with this compound. No known research data for filbert bud mite.

Biological control:

- None known.

Cultural control:

- None known.

Filbert Leafroller (*Archips rosana*)

The filbert leafroller adult is a buff-colored moth with brown bands and marks on its wings. Adult flight is monitored with pheromone traps, which are also used to monitor obliquebanded leafroller moths. Adults are active in early- to mid-summer and lay eggs that overwinter on twigs and branches. Larvae hatch in early spring and are green with a brown head. Larval feeding on buds reduces nut yields, destroying buds that would later develop into nuts. If scouting reveals that 20–25% of terminal buds have larvae (filbert + obliquebanded leafroller), treatment is recommended. However, chemical treatment for this pest is rare, since populations of naturally occurring beneficials (parasitoids) generally keep leafroller populations under control. The filbert leafroller has one generation per year.

Chemical control:

- Azadirachtin (Neemix and other brands). Not widely used. Organic growers use Entrust (better efficacy) instead of azadirachtin.

- *Bacillus thuringiensis* (Bt). Several brands available. Not widely used, because it is expensive and timing of application is very specific. Useful for organic production.
- Bifenthrin (Brigade and other brands). Currently not widely used. It is a newer registration. Growers have little experience with this product. It will be good for resistance management.
- Carbaryl (Sevin and other brands). Not used. Harsh on beneficials, which can then cause a flare-up of aphids and other pests.
- Chlorpyrifos (Lorsban and other brands). Commonly used if needed and is the product of choice. The fuming action of chlorpyrifos reaches the larvae that are rolled in the leaves.
- Diazinon. Supplemental label for Platte 500-AG. Used by some growers.
- Diflubenzuron (Dimilin). New registration. Growers have little experience with this product. Good for resistance management.
- Esfenvalerate (Asana). Useful for resistance management.
- Methoxyfenozide (Intrepid). Insect growth regulator. Useful for resistance management.
- Permethrin (Ambush, Pounce, and other brands). Useful for resistance management.
- Spinosad (Entrust, Success). Entrust formulation used mainly by organic growers.

Biological control:

- Naturally occurring parasitoids keep populations under control. Use pesticides judiciously to protect beneficial insects in the orchard.

Cultural control:

- None known.

Obliquebanded Leafroller (*Choristoneura rosaceana*)

The obliquebanded leafroller has two generations per year. Obliquebanded leafrollers overwinter as inactive, non-feeding, immature larvae on twigs and branches and ground debris. They become active in early spring and feed on buds and leaves, which may reduce yield by destroying nut buds. After feeding for a month or two, the mature larvae pupate in silken cocoons on the underside of leaves. Adults emerge after a week or two of pupation. Adult flight is monitored with pheromone traps. Adults mate immediately after emergence and lay eggs that hatch in about one week. These summer generation larvae are active in July. They feed primarily on leaves, but small larvae may also feed

under the husk on the developing nut. This feeding injury causes premature nut drop and occasionally produces substantial yield losses. There is a second adult flight in late summer and fall. Eggs laid by these moths hatch and the larvae feed briefly before spinning overwintering cocoons in protected sites on the trees.

The obliquebanded leafroller adult is a tan-colored moth with distinct, angled, brown bands on its wings. The larvae are bright green with a black head. If scouting during the spring reveals that 20 to 25% of terminal buds have larvae (obliquebanded + filbert leafrollers), treatment is recommended. Naturally occurring beneficial insects (parasitoids) generally keep the early population of leafrollers under control, and pesticide applications are rarely necessary.

Chemical controls are generally not specifically directed at the summer generation of the obliquebanded leafroller, because these larvae are usually suppressed adequately when the orchard is treated for control of the filbertworm.

Chemical control:

- Azadirachtin (Neemix and other brands). Not widely used. Organic growers use Entrust (better efficacy) instead of azadirachtin.
- *Bacillus thuringiensis* (Bt). Several brands available. Not widely used, because it is expensive and timing of application is very specific. Useful for organic production.
- Bifenthrin (Brigade and other brands). Currently not widely used. It is a newer registration. Growers have little experience with this product. It will be good for resistance management.
- Carbaryl (Sevin and other brands). Not used. Harsh on beneficials.
- Chlorpyrifos (Lorsban and other brands). Commonly used if needed and is the product of choice. The fuming action of chlorpyrifos reaches the larvae that are rolled in the leaves.
- Cyfluthrin (Baythroid). This is a newer registration. Growers have little experience with this product.
- Diazinon. Supplemental label for Platte 500-AG. Used by some growers.
- Diflubenzuron (Dimilin). This is a new registration. Growers have little experience with this product. Good for resistance management.
- Esfenvalerate (Asana). Useful for resistance management.
- Methoxyfenozide (Intrepid). Insect growth regulator. Useful for resistance management.
- Permethrin (Ambush, Pounce, and other brands). Useful for resistance management.

- Spinosad (Entrust, Success). Entrust formulation used mainly by organic growers.

Biological control:

- Naturally occurring parasitoids keep populations under control. Use pesticides judiciously to protect beneficial insects in the orchard.

Cultural control:

- None known.

Omnivorous Leaftier (*Cnephasia longana*)

The omnivorous leaftier is an economic pest only during the establishment period (non-bearing trees). Bearing orchards are not treated for this pest.

Larvae hatch from overwintering eggs in April and May and are carried into the orchard by the wind on silken threads. They are about ½ inch long and cream-colored with a lighter stripe along each side of the back. Larvae wiggle violently when disturbed. Adults are a tan moth about ½ inch long. Females have brown spots on their forewings. There is one generation per year.

Larvae feed on developing buds and terminal growth, resulting in malformed trees. Tree vigor and growth are also negatively affected. Early spring is the time to scout for larvae. If larvae are present, treatment is recommended.

Chemical control:

- *Bacillus thuringiensis* (Bt). Several brands available. Not widely used, because it is expensive and timing of application is very specific. Useful for organic production.
- Carbaryl (Sevin and other brands). Not used. Harsh on beneficials.
- Chlorpyrifos (Lorsban and other brands). Commonly used and is the product of choice. The fuming action of chlorpyrifos reaches the larvae that are protected in the leaves and buds.
- Diflubenzuron (Dimilin). New registration. Growers have little experience with this product. Good for resistance management.
- Methoxyfenozide (Intrepid). Insect growth regulator. Useful for resistance management.
- Spinosad (Entrust, Success). Entrust formulation used mainly by organic growers.

Biological control:

- None known.

Cultural control:

- None.

<u>Winter Moth</u> (*Operophtera brumata*)

The winter moth is an occasional pest in hazelnut orchards. Control treatments are usually not directed specifically at the winter moth. Instead, control is usually achieved when the orchard is treated for leafroller.

Adults are mottled brown moths about 1 inch long. Female moths are wingless. Adults are active during the winter months. After mating, females deposit eggs in the cracks and crevices of the tree bark. Larvae hatch in late winter and early spring and feed on newly opening buds, causing reduced nut yields. Larval feeding causes leaves to take on a torn or tattered appearance. Larvae are about 1 inch long and are bright green with a green head and a light-colored stripe on each side of the body. Larvae can balloon into fields from neighboring trees and shrubs. Scouting in early spring by inspecting terminals and leaves will reveal a winter moth larvae population.

Chemical control:

- *Bacillus thuringiensis* (Bt). Several brands available. Not widely used, because it is expensive and timing of application is very specific. Useful for organic production.
- Carbaryl (Sevin and other brands). Not used. Harsh on beneficials.
- Chlorpyrifos (Lorsban and other brands). Commonly used and is the product of choice. The fuming action of chlorpyrifos reaches the larvae that are protected in the leaves and buds.
- Diflubenzuron (Dimilin). New registration. Growers have little experience with this product. Good for resistance management.
- Methoxyfenozide (Intrepid). Insect growth regulator. Useful for resistance management.
- Spinosad (Entrust, Success). Entrust formulation used mainly by organic growers.

Biological control:

- Protect naturally occurring predators and parasitoids. These provide some aid in keeping winter moth populations under control.

Cultural control:

- None.

Critical Needs for Insect and Mite Management in Hazelnuts: Bud Break to Fully Formed Leaves

Research:

- Evaluate efficacy of spirodiclofen (Envidor) and pyridaben (Nexter, Pyramite) for control of filbert bud mite.
- Evaluate efficacy of cyfluthrin (Baythroid) for aphid control.
- Test the nontarget effects of pesticides on filbert aphid parasitoids.
- Develop best management practices for protecting beneficial insects in the orchard.
- Investigate the biology, ecology, and management of a new emerging pest, the large hazel aphid (*Corylobium avellanae*), and determine its economic impacts in hazelnut orchards.
- Determine the economic threshold for the filbert aphid. (Current recommendations are questionable.)
- Investigate the relationship and interaction of the aphids and parasitoids that are found in hazelnut orchards.
- Identify and evaluate cultural practices that may help manage aphids and protect beneficial parasitoids.
- Determine the influence of mowing the orchard on aphid populations.
- Refine monitoring techniques for the filbert bud mite (e.g., do populations fluctuate within a given day?).
- Investigate the damage caused by the filbert bud mite. Does it cause pollen shed and/or reduce the amount of pollen available for pollination?
- Determine an economic threshold for the filbert bud mite, and identify an economically feasible control.
- Investigate whether there are any natural predators of the filbert bud mite, and determine their role in population management.

Regulatory:

- If spirodiclofen (Envidor) is determined to be effective in controlling filbert bud mite, seek addition of this pest to the label.
- Maintain the registration of chlorpyrifos.

- Ensure that pesticide license recertification credits, granted by state departments of agriculture, will be awarded for all pest management training, including that covering unregistered pesticides.

Education:

- Continue to educate regulators about the critical need for maintaining the registration of chlorpyrifos (Lorsban and other brands).
- Inform pesticide registrants of the need to include hazelnuts on certain pesticide labels and to include specific pests on products already registered for use in hazelnuts (e.g., adding filbert bud mite to the Envidor [spirodiclofen] label).
- Once best management practices are developed, educate growers about how they can be used to ensure protection of naturally occurring beneficial insects in the orchard.
- Educate growers on the biology, ecology, management, and field identification of the large hazel aphid.

DISEASES

Eastern Filbert Blight (*Anisogramma anomala*)

This fungal disease is the most damaging and widespread disease of hazelnuts and can cause significant economic loss. If this disease is left uncontrolled, most of the trees in an orchard eventually are killed above the soil line. The fungus has a life cycle of two years or more, including a 12 to 15 month latent period when no symptoms are visible. Spores are spread by wind, and green tissue is the site of infection. Eastern filbert blight can also be introduced into an orchard on infected nursery stock.

In the early spring, wind-driven rain and splashing droplets spread spores to young developing buds and shoots. The disease then moves into the shoots and branches. After about 15 months, generally sometime in June, elongated, raised pustules begin to appear on branches and twigs. These pustules continue to expand until the fungus breaks through the outer bark, usually sometime in July or August. A white, oval-shaped structure called a stroma can be seen then. Stromata are arranged in relatively straight rows, lengthwise along the branch. As the stroma matures from August to October, it turns into a black canker that enlarges along the branch each year. Branches die back when expanding cankers girdle branches and limbs. Usually, most of the canopy of susceptible diseased trees is dead within seven to fifteen years.

For newly planted orchards, new cultivars that are less susceptible to eastern filbert blight are now available. Among the cultivars that are already planted in an established orchard there is a range of susceptibility to this disease. (See Table 3, page 6, in "Growing Hazelnuts in the Pacific Northwest," Oregon State University Extension publication #EC 1219.) The cultivar 'Gasaway' was the initial source of single-gene resistance to eastern filbert blight in the Oregon State University hazelnut breeding program. Recently, other germplasm with different resistance sites has been identified and is now being incorporated into the breeding efforts. The goal is to release cultivars that have multiple sites of resistance to eastern filbert blight. This should create a more robust and diverse form of resistance to the disease.

An integrated approach is required for adequate control of eastern filbert blight. Regular scouting, early detection, protective fungal sprays, pruning of diseased wood, and use of resistant cultivars are all components of a successful eastern filbert blight management program.

Chemical control:
New growth needs to be protected with fungicide applications starting at bud swell or bud break in early March and continuing at two week intervals until early May. When chemical controls are used, resistance management is important. Rotate chemical classes.

- Azoxystrobin (Abound). Not very effective.
- Boscalid + Pyraclostrobin (Pristine). Not used. Pyraclostrobin (Cabrio) alone is effective.
- Chlorothalonil (Bravo, Echo, and other brands). Widely used. Commonly used for the first application.
- Copper products. Often used for the first application at bud swell.
- Fenarimol (Rubigan). Non-bearing orchards only. Use allowed under Oregon SLN. Not very effective.
- Harpin protein (Messenger). Not used. Poor efficacy.
- Propiconazole (Orbit). Orbit is the most effective product available. It provides post-infection eradication.
- Pyraclostrobin (Cabrio). Very effective and used in rotation with other chemicals.
- Trifloxystrobin (Gem). Very effective and provides post-infection eradication.

- Triflumizole (Procure). Effective. Post-infection eradication properties are still being evaluated.

Biological control:

- None known at this time.

Cultural control:

- Replace susceptible pollinizer cultivars within the orchard with immune ones (e.g., Gamma, Delta, Epsilon, Zeta).
- Remove and destroy escaped seedlings and trees that lie beyond the orchard perimeter.
- Remove infected branches below cankered area. Burn prunings prior to bud break in the spring.
- Start sucker control early. Suckers can be a source of blight.
- Scout orchards for diseased branches.

Critical Needs for Disease Management in Hazelnuts: Bud Break to Fully Formed Leaves

Research:

- Identify and evaluate effective management tools, particularly biological tools, for eastern filbert blight.
- Identify and evaluate new chemical classes of fungicides that might be effective in controlling eastern filbert blight and that can be used in rotation with currently registered fungicides for resistance management.
- Determine and exploit the mechanism of eastern filbert blight disease resistance within the hazelnut plant.
- Continue genetic research for multiple-site resistance to eastern filbert blight.
- Identify and evaluate management practices that can interrupt eastern filbert blight development, reduce the number of spores, etc. (e.g., application of hydrated lime).

Regulatory:

- Expedite registration for promising new chemistries for eastern filbert blight control.
- Streamline the Section 18 process, enabling the hazelnut industry to quickly respond to pest outbreaks.

- Ensure that hazelnuts are included on new pesticide labels whenever almonds and pecans are registered (EPA Crop Group 14: Tree Nuts).

Education:

- Continue to educate growers about the biology, ecology, and management of eastern filbert blight and the importance of fungicide applications and of scouting for diseased branches.
- Communicate to pesticide manufacturers of propiconazole the need for brands other than Orbit. Competition may help bring costs down.
- Communicate to EPA and pesticide manufacturers the need to include hazelnuts on pesticide labels when almonds and pecans (the representative crops in EPA Crop Group 14: Tree Nuts) obtain a registration.
- Ensure continued legislative support for current right-to-farm laws.
- 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.

WEEDS

Mature orchards tend to have few weed problems, because shading inhibits weed establishment. However, wild garlic is a perennial weed that thrives under shady conditions. Younger orchards have more light penetration and thus more weeds. In young orchards a pre-emergence herbicide is often applied to the soil in the tree row in the early spring, and a postemergence herbicide is sometimes added to the tank mix if weeds are already present. Certain herbicides are allowed in non-bearing orchards that are not allowed in bearing orchards. 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. Spot spraying with a non-selective 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 pre-emergence herbicide with long residual properties is desirable so weeds are controlled all season. Application of pre-emergence herbicides is timed to last through harvest to allow weed growth through the winter. Vegetation on the orchard floor throughout the winter aids in erosion control and contributes to better surface water quality. As early in the spring as is possible, it is a common practice to apply a soil residual material combined with a contact material to

knock down existing vegetation and also get residual weed control. The soil residual materials need rainfall or irrigation following their application to be effective.

New shoots, or suckers, appear at the base of the hazelnut tree beginning at bud break, and they continue to sprout throughout the growing season. Sucker control is necessary to help keep the tree a single-stemmed plant, to remove a possible source 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.

Chemical control:
Foliage-active:

- 2,4-D amine (Saber and other brands). Broadleaf weeds. Commonly used.
- Carfentrazone-ethyl (Aim). Broadleaf weeds. Contact activity.
- Clethodim (Select). Grasses only. Non-bearing only.
- Fluazifop-P-butyl (Fusilade). Non-bearing only. Grasses only.
- Flumioxazin (Chateau). Very effective but expensive. Non-bearing only. Trees must be established at least one year; otherwise, tree damage may occur.
- Glufosinate-ammonium (Rely).
- Glyphosate (Roundup and other brands). Very effective and widely used.
- Oxyfluorfen (Goal). Efficacious and commonly used. Also has some soil activity.
- Paraquat (Gamoxone). Widely used. Contact activity. Kills just the plant material above the soil line.
- Sethoxydim (Poast). Grasses only.

Sucker control (*foliage-active*):

- 2,4-D amine (several brands). Use only those 2,4-D brands registered for sucker control in hazelnuts. Must use caution on young trees.
- Carfentrazone-ethyl (Aim). Efficacious at high rate but expensive. Lower rate less expensive but less efficacious. Used if drift from 2,4-D is a concern.
- Glufosinate-ammonium (Rely). Not widely used due to expense. It is sometimes used if drift from 2,4-D to sensitive neighboring crops (e.g., grapes) is a concern.
- Paraquat (Gramoxone). Most common product used for sucker control. Inexpensive and very efficacious.

Soil-active:

- Benefin + oryzalin (XL 2G). Non-bearing only. Not used.
- Diuron (Karmex, Direx). Widely used. Effective and inexpensive.
- Isoxaben (Gallery). Non-bearing only. Not used.
- Napropamide (Devrinol). Not used. Expensive and some weeds appear to be napropamide resistant.
- Norflurazon (Solicam). Not used. Expensive and controls only a narrow range of weeds found in hazelnut orchards. Breaks down easily and quickly in sunlight.
- Oryzalin (Surflan). Rarely used. Gentle on young trees.
- Oxyfluorfen (Goal). Commonly used and very effective. Also has foliage activity.
- Pendimethalin (Prowl H_2O). New registration. Growers have little experience with this product.
- Simazine (Princep). Widely used. Effective and inexpensive.
- Trifluralin (Treflan). Non-bearing only. Not used.

Biological control:

- None known.

Cultural control:

- Flail mowing weeds between the tree rows.
- Hand removal of suckers.
- Mulch (such as sawdust, compost, or straw) applied around the tree. However, organic mulches can invite rodents.

Critical Needs for Weed Management in Hazelnuts: Bud Break to Fully Developed Leaves

Research:

- Identify and evaluate effective management tools for control of wild garlic.

Regulatory:

- Expedite a label change for oxyfluorfen (GoalTender) to allow use during the growing season and not just during dormancy.

Education:

- Communicate to Dow AgroSciences the need to include hazelnuts on the GoalTender label and allow use during the growing season. The new oxyfluorfen formulation, GoalTender, is less volatile and would be safe to use during times other than dormancy.

NUT MATURATION

(July, August, September)

Flowers that have been pollinated during the winter are fertilized by about the end of June or early July, and nut development begins. The nuts continue to grow in size until the nut kernels are fully mature, sometime during September. Mature nuts drop to the ground during the month of September. To prevent damage to the harvestable nuts, vehicles and farm equipment are not driven in the orchard at this time. Any pest management must occur before nut drop or after harvest, which usually occurs during the month of October. The orchard floor is prepared for harvest sometime in August. Preparation involves flail mowing to remove weeds and blanks (nuts without kernels that drop prematurely) and re-leveling of the ground by filling in pot holes and smoothing out the soil surface.

Brown Stain is a malady that commonly occurs in hazelnut orchards and is noticed as the nuts mature. Its cause is unknown and, as such, no treatments are applied. A brownish liquid soaks the side or apical end of the nut, beginning when nuts are about half grown. The brown spots then become sunken, and the kernel may become misshapen. The interior of the shell may turn into a soft, brown, watery mass. Brown stain causes a reduction in nut quality and yield. Learning the cause of brown stain and identifying possible management strategies are research goals of the hazelnut industry.

Field activities that may occur during this period:

- Scouting (insects, diseases, weeds)
- Insecticide application
- Herbicide application
- Irrigation
- Flail mowing of row middles, as needed
- Sucker removal (chemical or mechanical) as needed
- Pruning for eastern filbert blight removal
- Re-leveling of the ground in preparation for harvest

INSECTS

Aphids

Filbert Aphid (*Myzocallis coryli*) and **Large Hazel Aphid** (*Corylobium avellanae*). These pests were discussed earlier in the "Bud-Break" section. The large hazel aphid is a new pest in hazelnut orchards. Its biology, ecology, and management have not been studied, but at this time they are assumed to be similar to the filbert aphid. Filbert aphid populations usually decline during the heat of the summer, and treatment is usually not necessary after July. If populations are high, they are usually suppressed when a pesticide application is made at this time for control of filbertworm. In the fall, winged forms of the aphid are produced. They lay eggs that overwinter on twigs and in crevices in the tree bark.

Chemical control:

- Azadirachtin (Neemix and other brands). Not very efficacious but useful for organic growers.
- Carbaryl (Sevin). Not used. Harsh on beneficials.
- Chlorpyrifos (Lorsban and other brands). Very seldom used in order to protect beneficial insects that help control the aphid population.
- Diazinon. Good efficacy. Use allowed on a supplemental label for Platte 500-AG.
- Endosulfan (Thiodan, Thionex). Not used much. It is harsh on beneficials and earthworms.
- Imidacloprid (Admire, Provado, and other brands). An effective aphicide but rarely used because of expense.

Biological control:

- Protect natural predators, especially the wasp *Trioxys pallidus.*

Cultural control:

- None.

Filbert Weevil (*Curculio occidentalis*)

The filbert weevil is a newly emerging pest in hazelnut orchards, although it has long been commonly found infesting acorns in natural stands of oak trees. Little is known about the filbert weevil's biology, ecology, or management in

hazelnuts. Adults are small, buff-colored beetles with a pronounced snout. As nuts mature, the adult female uses her proboscis to cut a small hole in the immature nut to deposit her eggs. The larvae develop within the nut and feed on the nut meat. After development within the nut, larvae exit the nut after it drops to the ground. Larvae are C-shaped, white with a dark brown head, and do not have legs. They burrow to a depth of about 10 inches and hibernate (pupate) for up to three years, emerging in the spring. Damage from the filbert weevil is similar in appearance to damage from the filbertworm; an exit hole is noticed in the shell of the mature nut. Management of the filbert weevil is not well defined, and management of the filbertworm may not be effective for the filbert weevil.

Chemical control:

- As it is a new pest, chemical controls have not been targeted at the filbert weevil.

Biological control:

- None known at this time.

Cultural control:

- It is believed that sanitation (e.g., flailing the orchard floor after harvest and the surrounding oak habitats) would be helpful in reducing weevil populations.

Filbertworm (*Melissopus latiferreanus*)

Filbertworm is the most serious insect pest in hazelnut production. It is a perennial pest and is widespread throughout all hazelnut-growing regions. Filbertworm larvae feed on developing nuts and can severely reduce nut quality and marketable yield.

The filbertworm adult is a gray to reddish colored moth, about ½ inch long, with brown/golden bands across each forewing. Adults emerge from silken cocoons some time in mid-June. When temperatures are above 60°F at dusk the moths mate and the female lays eggs singly on leaves near a developing nut cluster. Eggs hatch in about 7 to 10 days, and the newly emerged larvae, which are white with a brown head and about ½ inch long at maturity, move to the nut clusters. Here the young larvae crawl under the husk, tunnel between the husk and the top of the nut, and enter the nut through the micropile where the stem attaches to the nut. There is no visible sign of entry. The larvae feed on the kernel until they complete their development (usually about two to four weeks). They then

bore an exit hole through the shell and exit the nut to form cocoons for overwintering.

Pheromone traps are used to monitor adult flight activity. Traps are placed in the top third of the tree (unlike pheromone traps for leafrollers, which are placed in the tree about six feet above the ground). An action threshold has been established: treatment is recommended when four traps in the orchard each have two to three moths per trap, or when five or more moths are caught in any one trap.

The filbertworm has one generation per year, with an extended emergence period. There is some thought that there might be a second generation, especially if the first generation is early. However, it is not known whether the larvae that appear later in the season are truly a second generation or if they are just a result of late emergence from the earlier generation.

Many different synthetic pyrethroids are registered for use in hazelnuts for filbertworm control. All are efficacious and used. However, esfenvalerate (Asana) and permethrin (Pounce) are most often used because they are inexpensive.

Chemical control:

- Azadirachtin (Neemix and other brands). Not very effective but useful in organic production.
- *Bacillus thuringiensis* (Bt). Several brands available. Timing is critical for good efficacy. Used in organic production.
- Bifenthrin (Brigade and other brands). Not commonly used. Expensive.
- Carbaryl (Sevin and other brands). Little is used. Can be useful for those applicators who do not have a license to buy and use restricted use pesticides.
- Chlorpyrifos (Lorsban and other brands). Not used. Poor efficacy, which may be due to temperature sensitivity. (Conditions are warm when treatment for filbertworm occurs.)
- Cyfluthrin (Baythroid). Effective. A newer registration. Growers have little experience with this product, but they are beginning to use it.
- Diazinon. Not used. Short residual and harsh on beneficials.
- Diflubenzuron (Dimilin). Used in rotation for resistance management.
- Deltamethrin (Decis). Not used.

- Esfenvalerate (Asana). Most commonly used. (About 80% of all filbertworm treatments are with esfenvalerate.) Very efficacious, inexpensive, and its long residual provides extended control.
- Lambda-cyhalothrin (Warrior).
- Methoxyfenozide (Intrepid). Very effective but not widely used because of expense. Needed for resistance management.
- Permethrin (Ambush, Pounce, and other brands). Commonly used. Effective and inexpensive.
- Pyriproxyfen (Esteem). Efficacious and often used.
- Spinosad (Entrust, Success). Entrust formulation is used in organic production.
- Tebufenozide (Confirm). Very effective but not widely used because of expense. Needed for resistance management.

Biological control:
- None known.

Cultural control:
- Adjacent area management (spray or remove trees from abandoned orchards; remove volunteer/wild hazelnut trees).

Obliquebanded Leafroller (*Choristoneura rosaceana*)

This pest was discussed earlier in the "Bud Break" section. The summer generation of larvae feeds on nuts and leaves in early July. Treatment for the obliquebanded leafroller is usually directed at the larvae that are present earlier in the season. But sometimes control is necessary for the summer generation of larvae, which is active during nut maturation. However, these larvae are usually suppressed adequately when the orchard is treated for control of the filbertworm.

Chemical control (treatment is targeted toward adult moths):
- Azadirachtin (Neemix and other brands). Not widely used. Organic growers use Entrust (better efficacy) instead of azadirachtin.
- *Bacillus thuringiensis* (Bt). Several brands available. Not widely used, because it is expensive and timing of application is very specific. Useful for organic production.
- Bifenthrin (Brigade and other brands). Currently not widely used. Newer registration. Growers have little experience with this product. Will be good for resistance management.

- Carbaryl (Sevin and other brands). Not used. Harsh on beneficials.
- Chlorpyrifos (Lorsban and other brands). Commonly used if needed and is the product of choice. The fuming action of chlorpyrifos reaches the larvae that are rolled in the leaves.
- Cyfluthrin (Baythroid). Newer registration. Growers have little experience with this product.
- Diazinon. Supplemental label for Platte 500-AG. Used by some growers.
- Diflubenzuron (Dimilin). New registration. Growers have little experience with this product. Good for resistance management.
- Esfenvalerate (Asana). Useful for resistance management.
- Methoxyfenozide (Intrepid). Insect growth regulator. Useful for resistance management.
- Permethrin (Ambush, Pounce, and other brands). Useful for resistance management.
- Spinosad (Entrust, Success). Entrust formulation used mainly by organic growers.

Biological control:

- Naturally occurring parasitoids keep populations under control. Use pesticides judiciously to protect beneficial insects in the orchard.

Cultural control:

- None.

Critical Needs for Insect Management in Hazelnuts: Nut Maturation

Research:

- Identify and evaluate new and effective chemistries for filbertworm control (especially for use in rotation for resistance management).
- Continue to research the biology, ecology, and management of filbertworm.
- Identify and evaluate biological controls (especially viruses) for filbertworm.
- Investigate mating disruption (with pheromones) for filbertworm and the application technology involved in delivering the pheromone to the orchard. Any system designed needs to be inexpensive.
- Investigate "attract and kill" technology for filbertworm control.
- Investigate kairomone technology that will attract female filbertworm moths to a trap.

- Evaluate the reliability of pheromones currently used for filbertworm and leafroller monitoring.
- Improve the phenology model for predicting filbertworm emergence and flight.
- Investigate if filbertworms are coming from oak trees, and determine if there are filbertworm biotypes.
- Design and evaluate tank mixes that combine different pesticide chemistries with synthetic pyrethroid chemistry to improve efficacy.
- Determine if there is growing resistance to esfenvalerate (Asana) by the filbertworm.
- Investigate the biology, ecology, and management of an emerging pest, the filbert weevil, newly found in hazelnut orchards. Damage associated with the filbertworm might actually be caused by this new weevil pest.

Regulatory:

- Maintain the registration of esfenvalerate.
- Ensure that pesticide license recertification credits, granted by state departments of agriculture, will be awarded for all pest management training, including that covering unregistered pesticides.

Education:

- Communicate to regulators the need for maintaining the registration of esfenvalerate (Asana) for filbertworm control.
- Inform pesticide registrants of the need to include hazelnuts on certain pesticide labels and to include specific pests on products already registered for use in hazelnuts.
- Continue to educate growers and pest managers about the biology, ecology, and management of filbertworm.

DISEASES

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

The causal agent of this disease, a bacterium, is also known as *Xanthomonas campestris* pv. *corylina*. Bacterial blight is widespread in hazelnut orchards and is especially harmful and problematic in young (1 to 5 years old) and newly planted orchards. Cankers or lesions caused by the disease can girdle trunks and kill trees up to 10 years old. The bacterium attacks buds, leaves, branches, and trunk and enters through wounds. It is spread through rain splash or infected nursery stock. Symptoms first appear as small, angular or round, yellowish-

green, water-soaked spots on leaves. Diseased areas later turn reddish brown. On current-season stems, dark green, water-soaked areas appear, later turning reddish brown. Eventually, lesions develop.

Copper is the only known effective treatment for bacterial blight disease.

Chemical control:

- Copper products. Very effective. Non-bearing trees are treated in September before the fall rains begin. A second application may be applied in October. Bearing trees are treated after harvest.

Biological control:

- None known.

Cultural control:

- Plant pathogen-free nursery stock.
- Prune out infected twigs and branches.
- Reduce stress and maintain healthy, vigorous trees. Irrigate young orchards for the first three years to reduce stress.

Critical Needs for Disease Management in Hazelnuts: Nut Maturation

Research:

- Investigate whether another bacterium, *Pseudomonas,* is also causing bacterial blight. If it is, determine correct timing of copper applications.
- Identify and evaluate new chemistries that are effective in controlling bacterial blight, especially for resistance management.
- Test *Xanthomonas* for copper resistance.
- Investigate whether a treatment application in January is effective for bacterial blight management.

Regulatory:

- Expedite the registration of any new chemistry that is effective in controlling bacterial diseases.

Education:

- Continue to educate growers about the biology, ecology, and management of bacterial blight, the importance of scouting young orchards, and the importance of copper sprays to keep trees healthy.

WEEDS

Except for purposes of sucker removal, herbicides are seldom applied during this time period. Suckers are removed as needed. Sometimes weeds around the perimeter of the orchard need to be controlled. This is often accomplished by spot-spraying with a postemergence herbicide such as glyphosate or paraquat. Flail mowing as needed between the tree rows is common.

Chemical control:
Sucker control (*foliage-active*):

- 2,4-D amine (several brands). Use only those brands that allow sucker control in hazelnuts. Must use caution on young trees.
- Carfentrazone-ethyl (Aim). Efficacious at high rate but expensive. Lower rate less expensive but less efficacious. Used if drift from 2,4-D is a concern.
- Glufosinate-ammonium (Rely). Not widely used due to expense. It is sometimes used if drift from 2,4-D to sensitive neighboring crops (e.g., grapes) is a concern.
- Paraquat (Gramoxone). Most common product used for sucker control. Inexpensive and very efficacious.

Biological control:

- None known.

Cultural control:

- Hand removal of suckers (if they are too tall to be controlled with an herbicide).
- Flail mowing between the tree rows.

Critical Needs for Weed Management in Hazelnuts: Nut Maturation

There are no critical weed management needs specific to this time period. The needs stated in the "Bud Break" section summarize the general weed management needs during the hazelnut growing season.

HARVEST AND POST HARVEST

(October and November)

Harvest generally occurs during the month of October. Leaves are dropping during November, and by the end of November trees are beginning to enter dormancy.

Prior to harvest, during September, nuts have fallen from the tree to the orchard floor. Once most of the nuts have fallen, harvest begins. All commercially grown hazelnuts are harvested mechanically. Harvest is 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.

Not much pest management occurs during this time period, except that moss and lichen growing on the trees are sometimes controlled. Moss and lichen do not feed on the trees, but they collect moisture that increases the weight of the limbs. This can cause limb breakage during heavy, wet snows or ice storms. After harvest and prior to the fall rains, copper products and/or lime sulfur products are applied to kill moss and lichen that are growing on the trees. Copper application at this time also aids in the management of bacterial blight.

Field activities that may occur during this period:

- Harvest: sweep nuts into windrows, and harvest mechanically.
- Transport nuts to cleaning and drying facility.
- Treat moss and lichen with copper and/or lime sulfur after harvest.
- Sucker control after harvest, if needed.

INSECTS

No insect management is practiced at this time.

DISEASES

Bacterial Blight (*Xanthomonas arboricola* pv. *corylina*)
The causal agent of this disease, a bacterium, is also known as *Xanthomonas campestris* pv. *corylina*. Bacterial blight was discussed earlier in the "Nut

Maturation" section. An application of copper, the only known effective treatment for bacterial blight disease, is made after harvest. Non-bearing trees receive a copper treatment in September, and a second application is often made in October. Young bearing trees are treated with copper after harvest.

Chemical control:

- Copper products. Very effective. Bordeaux is preferred at this time. Bordeaux mixtures tend to "stick" better under rainy conditions.

Biological control:

- None known.

Cultural control:

- Prune out infected twigs and branches.
- Sanitize pruning equipment to reduce spread of the disease from tree to tree.
- Reduce stress and maintain healthy, vigorous trees.

Kernel molds

The exact cause of this disease is unknown, and no control treatments are applied. However, several causal agents are associated with this disease. *Mycosphaerella punctiformis* is associated with kernel tip mold; *Phomopsis* species and *Septoria ostryae* are associated with internal kernel discoloration; and *Nematospora coryli* (a yeast) is associated with kernel spot. The amount and type of kernel mold varies from year to year. It is prudent, if possible, not to let nuts remain on the ground too long prior to harvest, where they may pick up moisture. Much is unknown about kernel mold.

Critical Needs for Disease Management in Hazelnuts: Harvest and Post Harvest

Research:

- Investigate the cause of kernel molds and identify management tools for control.
- Investigate whether another bacterium, *Pseudomonas,* is also causing bacterial blight. If it is, determine correct timing of copper applications.
- Identify and evaluate new chemistries that are effective in controlling bacterial blight, especially for resistance management.

- Test *Xanthomonas* for copper resistance.
- Investigate whether a treatment application for bacterial blight in January is effective.

Regulatory:

- Expedite the registration of any new chemistry that is effective in controlling bacterial diseases.

Education:

- Continue to educate growers about the biology, ecology, and management of bacterial blight, the importance of scouting young orchards, and the importance of copper sprays to keep trees healthy.

WEEDS

Except for possibly the perimeter of the orchard and spot spraying hard-to-control perennial weeds in the orchard, weed management is not practiced during or after harvest. Mature orchards tend to have few weeds, due to excessive shading from the trees. Weeds in young orchards are often left to grow to prevent soil erosion during the winter and to maintain surface water quality. Sucker control may be done, if needed, after harvest.

The chemical and biological control practices for weeds and suckers during this time period are the same as those mentioned in the "Bud Break" section of this document. Cultural methods for weed or sucker control after harvest do not include flail mowing, as at bud break, but they do include hand removal of suckers, if needed, and mulching around the base of trees.

Critical Needs for Weed Management in Hazelnuts: Harvest and Post Harvest

There are no critical weed management needs specific to this time period. The needs stated in the "Bud Break" section summarize the general weed management needs during the hazelnut growing season.

Vertebrate Pests and their Management

(Birds, deer, elk, gophers, moles, squirrels, and 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.

Birds

Crows and jays (Stellar and Scrub Jays) congregate in hazelnut orchards and can consume large quantities of nuts.

Chemical control:

- Chemical repellents are not used.

Biological control:

- None known.

Cultural control:

- Auditory frightening devices. Propane cannons are sometimes used, but their affects don't last very long. (Birds become habituated to the sound.)
- Shooting. A common practice.
- Trapping. Not common.

Deer and Elk

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

Chemical control:

- Chemical repellants: various brands are available for use that interrupt deer feeding by providing an unpleasant taste or disagreeable odor, but their effectiveness is generally inconsistent.

- Garlic oil. Used with success by some growers.

Biological control:
- None known.

Cultural control:
- Physical barriers (e.g., fences). These offer the best control and should be installed around a new hazelnut orchard prior to or immediately after planting if deer and elk are known to be a problem in the area. Although effective, fencing is expensive and usually cost-prohibitive for almost all growers.
- Shooting. Deer and elk populations may be controlled by growers who apply for a crop damage permit, which allows landowners to destroy animals that are causing damage. This method is most effective for solitary deer or infrequent visitations.

Gopher and Moles

Gophers feeding on roots and tree bark can kill young trees. 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 soil surface, created as they burrow under the ground. Gophers are especially attracted to orchards that have a succulent cover crop or other vegetation between the tree rows.

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

Chemical control:
- Aluminum phosphide (Phostoxin). Pellets are applied to holes, burrows, or underground tunnels, and phosphine gas is released. Effective for gopher control but not very effective for moles.
- Strychnine bait. Used for gopher control. Works well but is little used in orchards. Not readily available.
- Sulfur. Burning sulfur in tunnels and holes. A practice used by some growers. Works best when soil moisture is high (when tunnels are slick and sealed).

Biological control:

- Installation of owl boxes and perches for hawks. Used by many growers. Helps reduce gopher population.

Cultural control:

- Trapping. Effective but time consuming and impractical.

Squirrels

Squirrels are fond of hazelnuts and the bark on young 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.

Chemical control:

- Aluminum phosphide (Phostoxin). Pellets are applied to holes or burrows, and phosphine gas is released. Works best and is mostly used in the spring when the soil is moist and squirrel holes are open.
- Strychnine bait. Worked well in the past but is no longer available for use in hazelnuts.

Biological control:

- None known.

Cultural control:

- Trapping and shooting. A permit is needed for certain squirrel species (e.g., western and eastern silver gray squirrels). Trapping works well but is time consuming, impractical, and doesn't 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.

Voles depend on cover for protection, and 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 two to five years. Severe vole damage can reduce plant vigor, lower nut yields, and cause plant mortality.

Chemical control:

- Zinc phosphide bait. Can be used during dormancy but must be applied to the orchard floor where there is vegetation. (The label does not allow use on bare soil.) Not widely used by growers.
- Burning sulfur in tunnels and holes. Not very efficacious.

Biological control:

- Installation of owl boxes and perches for hawks. Used by many growers. Helps reduce vole population in the orchard.

Cultural control:

- Adjacent area management (mowing around orchard borders).
- Habitat reduction: mowing in and between tree rows.
- Plant guards that are placed around tree trunk to prevent sun scald also inhibit above-ground vole feeding.

Critical Needs for Vertebrate Management in Hazelnuts

Research:

- Identify and evaluate an effective squirrel bait. It should be quick-acting, economical, and not cause secondary poisoning of nontarget species.
- Identify and evaluate effective chemical repellents for birds.
- Investigate noise repellents or other sound devices for birds that are effective and have long-lasting effects.

Regulatory:

- Ask federal regulators to extend the shooting season in which jays can be controlled.
- Reduce or remove noise restrictions for vertebrate control.
- Register zinc phosphide in hazelnuts for vole control.

Education:

- Educate growers about scouting techniques for vertebrate pests.
- When effective vertebrate controls are identified, communicate these findings to growers.

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Appendices

Activity Tables for Oregon and Washington Hazelnuts

Note: An activity may occur at any time during the designated time period.

Cultural Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Fertilization (granular) – Potassium	XXXX	XXXX									XXXX	XXXX
Fertilization (granular) – Nitrogen			XXXX	XXXX								
Fertilization (foliar) – Boron					XX							
Fertilization (foliar)				XXXX	XXXX		XXXX	XXXX			XXXX	
Harvest and harvest preparation								XX	XXXX	XXXX	X	
Irrigation (young trees)					XX	X	X	X				
Leaf sampling (nutritional)								XXXX				
Lime application	XXXX	XXXX									XXXX	XXXX
Mowing row middles				XXXX	XXXX	XXXX	XXXX	XXXX				
Painting of tree trunks (young trees)			XX	XXXX	XXXX							
Planting	XXXX	XXXX	XX								XXXX	XXXX
Pruning	XXXX	XXXX									XXXX	XXXX
Soil testing (for nutrients)								XXXX				

Pest Management Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Bird control								XXXX	XXXX	XXXX	XXXX	XXXX
Fungicide application			XXXX	XXXX	XX						XXXX	
Herbicide application		XXX	XXXX	XXXX						X	XX	
Insecticide application				XXXX	XXXX	XXXX	XXXX	XXXX				
Moss and lichen control			XXXX								XXXX	XXXX
Pheromone traps (installing and checking)					XXXX	XXXX	XXXX	XX				
Pruning for eastern filbert blight	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX			XXXX	XXXX
Rodent control	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Scouting for diseases	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Scouting for insects and mites				XXXX	XXXX	XXXX	XXXX	XXXX				
Scouting for weeds			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX			
Sucker removal				XXXX	XXXX	XXXX	XXXX	XXXX				

Seasonal Pest Occurrence for Oregon and Washington Hazelnuts

Note:
Present = when the pest is active.
Treated = treatment may occur at any time during the designated time.

Insects		J	F	M	A	M	J	J	A	S	O	N	D
Filbert aphid (< 10% of acreage treated annually)	Present				XXXX	XXXX	XXXX	XXXX	XXXX	XXXX			
	Treated					XXXX	XXXX						
Filbert bud mite (< 5% of acreage treated annually)	Present		XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	
	Treated				XXXX								
Filbert leafroller (< 5% of acreage treated annually)	Present				XXXX	XXXX	X						
	Treated				XXXX	X							
Filbertworm (~ 98% of acreage treated annually)	Present						XXXX	XXXX	XXXX	XXXX			
	Treated							XXXX	XXXX				
Obliquebanded leafroller (~ 5% of acreage treated annually)	Present				XXXX	XXXX	X	XXXX	X	X	XX		
	Treated				XXX	XX							
Omnivorous leaftier (Non-bearing trees)	Present				XXXX	XXXX							
	Treated				XXXX	XXXX							
Winter moth (< 5% of acreage treated annually)	Present			XXXX	XXXX	XX							
	Treated				XXXX								
Diseases		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bacterial blight (100% of non-bearing trees treated)	Present	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
	Treated											XXXX	
Eastern filbert blight (~ 98% of acreage treated annually)	Present	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
	Treated			XXXX	XXXX	XXXX							
Weeds		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Annual Broadleaves:													
Such as: groundsel, knotweed, ladysthumb, lambsquarters, mayweed, mustards, prickly lettuce, purslane, pigweed, and sowthistle.	Present	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Treatment occurs as needed throughout the growing season.	Treated			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX			XXXX	
Perennial & Biennial Broadleaves:													
Such as: field bindweed, Canada thistle, yellow nutsedge, and wild garlic.	Present	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Treatment occurs as needed throughout the growing season.	Treated		XX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX			XXXX	
Grasses:													
Such as: barnyardgrass, annual bluegrass, crabgrass, annual ryegrass, quackgrass, and yellow foxtail.	Present		XX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XX	
Treatment occurs as needed throughout the growing season.	Treated		XX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX			XXXX	

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 hazelnut management system—more research needed; * = used but not a stand-alone management tool; NU = not used for this pest; chemistry or practice known to be ineffective.

MANAGEMENT TOOLS	Filbert aphid	Filbert bud mite	Filbert leafroller	Filbertworm	Obliquebanded leafroller	Omnivorous leaftier	Winter moth	COMMENTS
Registered Chemistries								
Azadirachtin (Neemix and other brands)	?	NU	?	?	?	?	?	Useful for organic production.
Bacillus thuringiensis (several brands)	NU	NU	?	?	?	?	?	Useful for organic production.
Beauveria bassiana (Mycotrol)	?	?	?	?	?	?	?	Useful for organic production.
Bifenazate (Acramite)	NU	?	NU	NU	NU	NU	NU	
Bifenthrin (Brigade and other brands)	NU	NU	?	?	?	?	?	
Calcium polysulfide (Lime sulfur, Sulforix, and others)	NU	F	NU	NU	NU	NU	NU	
Carbaryl (Sevin and other brands)	F	F	F	F	F	F	F	
Chlorpyrifos (Lorsban and other brands)	G-E	NU	G-E	P	G-E	G-E	G-E	
Cyfluthrin (Baythroid)	?	NU	?	?	?	?	?	
Deltamethrin (Decis)	?	NU	?	?	?	?	?	
Diazinon	G	NU	F	P	F	F	F	Supplemental label for Platte 500-AG.
Dicofol (Dicofol, Kelthane)	NU	F	NU	NU	NU	NU	NU	
Diflubenzuron (Dimilin)	NU	NU	?	?	?	?	?	
Endosulfan (Thiodan and other brands)	F	G	F	?	F	F	F	
Esfenvalerate (Asana)	P	NU	E	E	E	E	E	
Etoxazole (Zeal)	NU	NU	NU	NU	NU	NU	NU	
Gamma-cyhalothrin (Proaxis)	NU	?	NU	NU	NU	NU	NU	
Hexythiazox (Savey)	NU	NU	NU	NU	NU	NU	NU	
Imidacloprid (Admire and other brands)	G?	NU	NU	NU	NU	NU	NU	
Imidacloprid (Provado and other brands)	G?	NU	NU	NU	NU	NU	NU	
Lambda-cyhalothrin (Warrior)	P-F	NU	G	G	G	G	G	
Methoxyfenozide (Intrepid)	NU	NU	G	G-E	G	?	G	Timing is critical for good efficacy.
Oxydemeton-methyl (MSR)	G	NU	NU	NU	NU	NU	NU	
Permethrin (Ambush, Pounce)	P	NU	F-G	F-G	F	F-G	F-G	
Phosmet (Imidan)	NU	NU	F	F	F	F	F	
Pyrethrin (Pyganic and other brands)	P	P	P	P	P	P	P	Useful for organic production.
Pyridaben (Nexter, Pyramite)	NU	?	NU	NU	NU	NU	NU	
Pyriproxyfen (Esteem)	?	NU	?	G	?	?	?	
Spinosad (Entrust, Success)	NU	NU	F-G	?	F-G	?	?	Entrust useful in organic production.
Spirodiclofen (Envidor)	NU	G-E	NU	NU	NU	NU	NU	
Tebufenozide (Confirm)	NU	NU	G	G-E	G	?	G	Timing is critical for good efficacy.
Unregistered/New Chemistries								
Fenpropathrin (Danitol)	?	?	?	?	?	?	?	
Indoxacarb (Avaunt)	?	?	?	?	?	?	?	
Rynaxypyr (Altacor)	?	?	?	?	?	?	?	
Thiacloprid (Calypso)	?	?	?	?	?	?	?	
Biological								
None								

MANAGEMENT TOOLS	Filbert aphid	Filbert bud mite	Filbert leafroller	Filbertworm	Obliquebanded leafroller	Omnivorous leaftier	Winter moth	COMMENTS
Cultural/Non-Chemical								
Adjacent area management	NU	NU	NU	*	NU	NU	NU	
Protection of beneficial arthropods	E *	E *	E *	E *	E *	E *	E *	
Pruning	NU	NU	NU	NU	NU	NU	NU	
Sanitation (remove nuts, prunings)	NU	NU	NU	NU	NU	NU	NU	
Weed management	NU	NU	NU	NU	NU	NU	NU	

Efficacy Ratings for DISEASE 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; NU = not used for this pest; * = used but not a stand-alone management tool.

MANAGEMENT TOOLS	Bacterial Blight	Eastern Filbert Blight	COMMENTS
Registered Chemistries			
Azoxystrobin (Abound)	NU	F-G	
Bacillus subtilis (Serenade)	P	NU	
Boscalid + Pyraclostrobin (Pristine)	NU	NU	
Chlorothalonil (Bravo and other brands)	NU	E	
Copper, Fixed (Bordeaux, Champ, Kocide)	G-E	G	
Fenarimol (Rubigan)	NU	P	Non-bearing orchards. SLN for OR.
Neem oil (Trilogy)	P	NU	
Harpin protein (Messenger)	P	P	
Horticultural Mineral Oil	NU	NU	
Phosphorous acid (Fosphite and other brands)	NU	NU	
Propiconazole (Orbit)	NU	E	
Pyraclostrobin (Cabrio)	NU	E	
Sulfur	NU	NU	
Trifloxystrobin (Gem)	NU	E	Unlike other strobies, has “kick-back” activity.
Triflumizole (Procure)	NU	G-E	
Unregistered/New Chemistries			
Trifloxystrobin + tebuconazole (Absolute)	NU		
Tebuconazole (Elite)	NU	G-E	
Thiram	NU		
Ziram	NU		
Captan	NU		
Sylitt (Dodine)	NU		
Biological			
None			
Cultural/Non-Chemical			
Adjacent area management	*	*	For eastern filbert blight, remove and destroy seedling volunteers.
Crop rotation	NU	NU	
Cultivar/rootstock selection	*	G-E	
Irrigation management	*	NU	
Pruning methods	*	G*	Burn or remove eastern filbert blight pruning piles.
Sanitation (removal of infected material)	*	G*	
Sun scald protection	*	NU	
Weed management	NU	NU	

Efficacy Ratings for WEED Management Tools in Hazelnuts

Efficacy ratings for weed management tools in hazelnuts are not provided, because weed management is not a major issue in hazelnut production. While weed management is important in a newly established orchard where the soil has recently been disturbed and young trees allow the light penetration needed for weed growth, it is not a major concern in an established orchard where trees shade out most weeds.

In a newly established orchard the pre-emergence herbicides of choice applied to the soil in tree rows are diuron (Karmex and other brands) and simazine (Princep and other brands), because they are effective and inexpensive. To prevent resistance and weed shifts, other pre-emergence herbicides are applied in rotation with diuron and simazine. Organic mulch (such as sawdust or straw) is sometimes applied around a newly planted tree to help suppress annual weeds. Planting a cover crop between the tree rows is not common. However, native vegetation is often allowed to grow between the tree rows and is mowed throughout the growing season. Sometimes an herbicide, such as 2,4-D, is applied to the vegetation strip to remove broadleaf weeds and allow just the grasses to grow. Hard-to-control perennial weeds, such as Canada thistle, field bindweed, morningglory, yellow nutsedge, and wild garlic are often treated successfully with either glyphosate or paraquat, which are applied to actively growing weeds. Oxyfluorfen (Goal), which has both pre- and post-emergence activity, is also commonly used for the weeds that occur in hazelnut orchards. Wild garlic is especially problematic in some orchards, because it can thrive under the shady conditions that are found in mature hazelnut orchards and is difficult to control with most herbicides. Few herbicides registered for use in hazelnuts are effective in controlling wild garlic.

Herbicides that are specific for postemergence grass control, such as clethodim, fluazifop-P-butyl, and sethoxydim, are not widely used, because while they are effective, they are relatively expensive and are specific to grasses. Grass weeds in the tree rows are more often controlled with a non-selective postemergence herbicide such as glyphosate, which will control both grass and broadleaf weeds.

Following is a list of herbicides registered for use in hazelnuts. A list of some of the common weeds found in hazelnut orchards also follows.

Registered Chemistries	Type of Activity*	Comments
2,4-D (Saber, Savage)	Post	Also used for sucker control.
Benfluralin (XL 2G)	Pre	Non-bearing only.
Carfentrazone-ethyl (Aim)	Post	Also used for sucker control.
Clethodim (Select)	Post	Grasses only. Non-bearing only.
Diclobenil (Casoron)	Pre	
Diquat (Reglone)	Post	Non-bearing only.

Registered Chemistries	Type of Activity*	Comments
Diuron (Karmex and others)	Pre	Widely used. Very effective.
Fluazifop-P-butyl (Fusilade)	Post	Grasses only. Non-bearing only.
Flumioxazin (Chateau)	Post	Non-bearing only.
Glufosinate-ammonium (Rely)	Post	Also used for sucker control.
Glyphosate (Roundup)	Post	Commonly used.
Isoxaben (Gallery)	Pre	Non-bearing only.
Napropamide (Devrinol)	Pre	
Norflurazon (Solicam)	Pre	
Oryzalin (Surflan)	Pre	
Oxyfluorfen (Goal)	Pre & Post	Commonly used. Effective.
Paraquat (Gramoxone)	Post	Commonly used.
Pelargonic acid (Scythe)	Post	Also used for sucker control.
Pendimethalin (Prowl H_20)	Pre	
Sethoxydim (Poast)	Post	Grasses only.
Simazine (Princep)	Pre	Widely used. Very effective.
Trifluralin (Treflan)	Pre	Non-bearing only.
Cultural Practices:		
Equipment sanitation	NA	Helpful.
Mowing	NA	Common. Prevents weed seed. production.
Mulch (around young trees)		Helpful for suppression of annual weeds.

*Pre = soil active—applied to the soil prior to weed emergence; Post = foliage active—applied to already-emerged weeds.

Weeds Commonly Found in Hazelnut Orchards

Annual broadleaf weeds	Perennial weeds	Grass weeds
Groundsel	Canada thistle	Barnyardgrass
Knotweed	Field bindweed	Bluegrass, annual
Lambsquarters	Morningglory	Ryegrass, annual
Mayweed/dogfennel	Yellow nutsedge	Quackgrass
Mustards	Wild garlic	
Pigweed		
Prickly lettuce		
Purslane		
Smartweed/ladysthumb		
Sowthistle		

Toxicity Ratings for Beneficials in Oregon and Washington Hazelnuts

Key to Beneficials:
BEB = Big-eyed bug (*Geocoris pallens*)
DB = Damsel bug (*Nabis alternatus*)
HB = Honey bee (*Apis mellifera*)
LW = Lacewings (*Chrysopa* spp.)
LB = Lady beetles (*Hippodamia convergens*)
MPB = Minute pirate bugs (*Orius* spp.)
PM = Predatory mites (*Acari: Phytoseiidae*)
PN = Parasitic nematodes
PW = Parasitic wasps (*Ichneumonidae* and *Braconidae* families, including *Trioxys pallidus*)
S = Spiders (*Arachnida: Araneae*
SF = Syrphid flies
TF = Tachinid flies

Rating Scale: O = Non-toxic; L = Slightly toxic; M = Moderately toxic; H = Highly toxic; ND = No Data

	BEB	DB	HB	LW	LB	MPB	PM	PN	PW	S	SF	TF	COMMENTS
Registered Material:													
Insecticides/Miticides:													
Azadirachtin (Neemix, Azatin, Azatrol)	L	L	L	L	L	L	L	ND	L	L	L	L	
Bacillus thuringiensis (Bt)	O	O	O	O	O	O	O	O	O	O	O	O	
Beauveria bassiana (Mycotrol)	ND	ND	ND	O	ND	ND	ND	ND	O	ND	ND	ND	
Bifenazate (Acramite)	L	L	L	L	L	L	L	ND	L	L	L	L	
Bifenthrin (Brigade and other brands)	M	H	H	M	H	H	H	ND	H	H	H	H	
Calcium polysulfide (lime sulfur, Suforix)	L	ND	O	M	M	H	L	ND	M	ND	M	M	
Carbaryl (Sevin, others)	M	M	H	M	H	M	H	ND	M	M	M	M	
Chlorpyrifos (Lorsban, others)	H	H	H	H	H	H	H	H	H	H	H	H	
Cyfluthrin (Baythroid)													ND for all.
Deltamethrin (Decis)													ND for all.
Diazinon	M	M	H	M	M	M	H	ND	L	M	H	ND	
Dicofol (Dicofol, Kelthane)	M	M	M	L	M	M	M	H	M	M	M	M	
Diflubenzuron (Dimilin)													ND for all.
Endosulfan (Thiodan and other brands)	M	M	M	M	M	M	M	L	M	M	M	M	
Esfenvalerate (Asana)	M	H	O	M	H	H	H	ND	H	H	H	H	
Etoxazole (Zeal)													ND for all.
Gamma-cyhalothrin (Proaxis)													ND for all.
Hexythiazox (Savey)	L	L	L	L	L	L	L	ND	L	L	L	L	
Imidacloprid (Admire)	L	L	L	L	L	L	L	ND	L	L	L	L	
Imidacloprid (Provado)	M	M	M	M	M	M	M	ND	M	M	M	M	
Lambda-cyhalothrin (Warrior)	M-H	M-H	O	M-H	M-H	M-H	H	ND	M-H	H	M-H	M-H	
Methoxyfenozide (Intrepid)	M?	M?	ND	ND	ND	ND	ND	ND	O	ND	ND	ND	Low probability of harm to beneficials.
Oxydemeton-methyl (Metasystox-R)	H	H	H	H	H	H	H	H	H	H	H	H	
Permethrin (Ambush, Pounce)	M	M	O	M	M	M	M	ND	M	M	M	M	
Phosmet (Imidan)	L-M	L-M	M	M	M	M	M	O	M	M	M	M	
Pyrethrin (Pyganic, others)	M	M	O	L	M	M	H	ND	M	H	M	M	
Pyridaben (Nexter, Pyramite)													ND for all.

	BEB	DB	HB	LW	LB	MPB	PM	PN	PW	S	SF	TF	COMMENTS
Pyriproxyfen (Esteem)	M	M	M	O	ND	ND	ND	L-M	M	ND	ND	ND	
Spinosad (Entrust, Success)	M	M	M	M	M	M	M	ND	M	M	M	M	
Spriodiclofen (Envidor)													ND for all.
Tebufenozide (Confirm)	O	O	O	O	O	O	O	ND	O	O	O	O	
Fungicides:													
Azoxystrobin (Abound)													ND for all.
Bacillus subtillis (Serenade)													ND for all.
Boscalid + Pyraclostrobin (Pristine)													ND for all.
Chlorothalonil (Bravo, Echo, and other brands)													ND for all.
Copper, fixed (several brands)	ND	ND	ND	ND	ND	ND	L	ND	ND	ND	ND	ND	
Fenarimol (Rubigan)													ND for all.
Neem oil (Triology)	L	L	L	L	L	L	L	ND	L	L	L	L	
Harpin protein (Messenger)													ND for all.
Horticultural mineral oil	M	M	ND	L	L	M	M	ND	L	L	ND	ND	
Phosphorous acid (Fosphite)													ND for all.
Propiconazole (Orbit)													ND for all.
Pyraclostrobin (Cabrio)													ND for all.
Sulfur	L	L	ND	M	M	H	L	ND	M	ND	M	M	
Trifloxystrobin (Gem)													ND for all.
Triflumizole (Procure)													ND for all.
Herbicides:													
2,4-D (several brands)	ND	ND	ND	O	L	ND	ND	ND	O-M	ND	ND	O	
Benefin +oryzalin (XL 2G)													ND for all.
Carfentrazone-ethyl (Aim)													ND for all.
Clethodim (Select)													ND for all.
Diclobenil (Casoron)													ND for all.
Diquat (Reglone)													
Diuron (Karmex and other brands)	ND	O	ND	ND	M	O	M	L	ND	ND	ND	ND	
Fluazifop-P-butyl (Fusilade)													ND for all.
Flumioxazin (Chateau)													ND for all.
Glufosinate-ammonium (Rely)	M	M	M	M	M	M	M	M	M	M	M	M	
Glyphosate (Roundup and other brands)	M	ND	ND	ND	ND	ND	H	ND	L	ND	ND	ND	
Isoxaben (Gallery)													ND for all.
Napropamide (Devrinol)													ND for all.
Norflurazon (Solicam)													ND for all.
Oryzalin (Surflan)													ND for all.
Oxyfluorfen (Goal)													ND for all.
Paraquat (Gramoxone and other brands)	ND	ND	ND	ND	ND	ND	H	ND	ND	ND	ND	ND	
Pendimethalin (Prowl H_20)													ND for all.
Sethoxydim (Poast)													ND for all.
Simazine (Princep and other brands)	ND	ND	ND	ND	M	ND	L	ND	M	ND	ND	ND	
Trifluralin (Treflan)	ND	ND	ND	ND	ND	ND	ND	ND	M-H	ND	ND	ND	
Unregistered/Potential chemistries													
Insecticides/Miticides:													
Fenpropathrin (Danitol)	M	M	L	M	M	M	M	ND	M	H	M	M	ND for all.
Indoxacarb (Avaunt)	L	L	L	L	L	L	L	ND	L	L	L	L	ND for all.

	BEB	DB	HB	LW	LB	MPB	PM	PN	PW	S	SF	TF	COMMENTS
Rynaxypyr (Altacor)													ND for all.
Thacloprid (Calypso)													ND for all.
Fungicides:													
Captan	ND	ND	ND	L	M	L	L	ND	L	ND	M	L	
Sylitt (Dodine)													ND for all.
Tebuconazole (Elite)													ND for all.
Thiram													ND for all.
Ziram	ND	ND	ND	ND	ND	L	ND	ND	ND	ND	ND	ND	
Herbicides:													
None													
Cultural/Non-Chemical:													
Adjacent area management	ND	ND	ND	ND	ND	ND	ND	ND	H	H	H	H	May be hazardous if habitat removed.
Crop rotation													Largely neutral.
Cultivar selection													Neutral.
Enhancing habitat for beneficials													Provides good habitat, shelter, and alternative prey for the beneficials.
Irrigation management													Neutral.
Row middle vegetation													Provides good habitat, shelter, and alternative prey for the beneficials.
Sanitation (remove nuts, prunings)													Neutral.
Straw mulch													May provide good habitat and shelter for some beneficials.
Weed control													May remove habitat or alternative prey for some species.