Pest Management Strategic Plan
for
Pacific Northwest Potato Production - REVISION

Summary of a workshop held on
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Lead Authors: Ronda Hirnyck, Lisa Downey
Editor: Sally O'Neal Coates

Contact Person:
Ronda Hirnyck, Idaho Pesticide Program Coordinator
(208) 364-4046
rhirnyck@uidaho.edu

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Previous Pest Management Strategic Plan

A Pest Management Strategic Plan (PMSP) for Pacific Northwest (PNW) Potato Production was produced in 2002, subsequent to a workshop held in February of that year. The potato industry in Alaska, Idaho, Oregon, and Washington determined in 2005 that the 2002 PMSP needed to be updated due to numerous changes impacting PNW potato production since the original document was produced. New pests have emerged as problematic (e.g., potato tuberworm, potato cyst nematode), pesticides have been canceled and registered, and new research on management strategies has been conducted since the original document. The industry decided to meet in 2006 to revise the PMSP document so that these changes were reflected.

Outcomes

A number of critical needs identified in the 2002 document have been addressed. Those research, regulatory, and educational priorities that have been addressed, completely or in part, are listed below along with subsequent outcomes.

Research Priorities

2002 Priority: Continue research on the relative importance of seed-borne vs. soil-borne inoculum for the diseases Verticillium wilt, black dot, Rhizoctonia, soft rot, dry rot, and silver scurf.

> ***Outcome:*** Research conducted in the Pacific Northwest has shown that silver scurf is almost exclusively caused by seed-borne inoculum. Research has also shown that the situation with Rhizoctonia is not as straightforward. Seed-borne Rhizoctonia is the major component of the disease cycle, but soil-borne inoculum also plays a role. Therefore, silver scurf management should focus on seed-borne inoculum, while Rhizoctonia management must address both seed and soil disease phases.

2002 Priority: To improve scouting efficiency, expand existing scouting programs, such as the Treasure Valley Pest Alert, to develop a regional early warning system.

> ***Outcome:*** The Treasure Valley Pest Alert Network has expanded and is now called the Pacific Northwest Pest Alert Network. In response to a newly emerged pest, the potato tuberworm (PTW), Oregon State University (OSU) and the Washington State Potato Commission (WSPC) developed a potato tuberworm alert system. Updated PTW counts for Oregon and Washington are sent to growers and industry personnel every week.

2002 Priority: Investigate early blight and white mold to understand more about the diseases, including how aggressive they are and what fungicides are effective against them.

Outcome: There has been extensive research on this subject in Washington and Idaho. Some of the research results were published by the University of Idaho Extension in 2003 in a bulletin entitled *White Mold on Potatoes* (CIS 1105).

2002 Priority: Develop chemicals and method of application for sprout suppression.

Outcome: The Idaho Potato Commission funded extensive research at the University of Idaho Potato Storage Research Facility in Kimberly on alternative methods for potato sprout control in storage. Chemicals detailed in the research included mint oils, clove oil, and hydrogen peroxide. Also investigated were timing and method of application for these chemicals. The results were detailed in a 2004 publication entitled *Organic and Alternative Methods for Potato Sprout Control in Storage* (University of Idaho Extension, CIS 1120).

2002 Priority: Continue area-wide IPM. Support cooperative decisions made at the regional level regarding CPB (Colorado potato beetle) and GPA (green peach aphid).

Outcome: Progress has been made in both Washington and Idaho. A regional pest-monitoring program was conducted over a 3-year period in Washington's Columbia Basin. Growers were encouraged to treat half their fields with a conventional "hard" program of insecticides and the other half with "soft" insecticides. Pest pressure in these fields was surveyed twice weekly, and the fields were monitored for leafroll virus at the end of the season. Growers using soft programs controlled the insects as well as or better than those using conventional hard programs, and in some cases those with the soft programs made fewer applications.

Regulatory Priorities

2002 Priority: Work with EPA in addressing FQPA issues to provide realistic and commonsense risk assessment data in order to avoid loss or cancellation of commonly used/needed pesticides.

Outcome: PNW potato industry leaders have hosted fact-finding, fumigant education, crop-specific, and larger agricultural tours attended by EPA personnel. Potato commission and potato grower group representatives in each state now have routine interaction with EPA, including personal visits in Washington, D.C. Additionally, the National Potato Council (NPC) is developing a method to collect pesticide usage data to further improve information flow between EPA and potato groups.

2002 Priority: Hasten registration of (DIPN) Amplify.

Outcome: DIPN (Amplify) has been registered.

Education Priorities

2002 Priority: Educate potato growers about importance and methods of scouting and economic thresholds.

> **Outcome:** This has been addressed by numerous publication in the PNW. In 2005, the *Best Management Practices Standards Checklist* was published. This checklist evaluates IPM practices currently in use, monitors changes in practices, encourages adoption of IPM practices, and is updated annually. In 2006, the University of Idaho Extension published *Diagnosis and Management of Potato Storage Diseases* (CIS 1131), an educational outreach tool about proper identification of diseases in storage. In addition, the *Potato Progress Newsletter*, a publication of the Washington State Potato Commission, addresses the education needs of growers in Idaho, Oregon, and Washington with respect to scouting, economic thresholds, and other pest management issues.

2002 Priority: Increase awareness of the importance of seed in spreading late blight and the difficulty of detection in seed.

> ***Outcome:*** Several grower-centered publications have arisen from the need to educate growers about the spread of late blight. One such publication, *Managing Late Blight on Irrigated Potatoes in the Pacific Northwest* (PNW 555, published in 2003), involved Oregon State University, University of Idaho, and Washington State University research and extension personnel. Continuing to address this need, University of Idaho Extension published *Late Blight Management Action Plan* (CIS 1132) in 2006.

2002 Priority: Teach resistance management strategies to preserve effectiveness of pesticides.

> ***Outcome:*** With a grant from Bayer Crop Science and with input from growers, the National Potato Council published three brochures to educate growers about resistance management strategies for plant diseases, weeds, Colorado potato beetles, and green peach aphids. These have been distributed throughout the PNW at grower field days and other grower- and education-centered activities. Additionally, researchers at the University of Idaho Extension published *Managing Fungicide Resistance* (CIS 1130) in 2006.

Work Group

A work group consisting of growers, commodity group representatives, pest control advisors, regulators, environmentalists, university specialists, and other technical experts from the Pacific Northwest states of Alaska, Idaho, Oregon, and Washington met on January 26, 2006, in Pocatello, Idaho to identify the needs of potato growers in their region regarding possible regulatory actions related to pesticides and the FQPA, and to revise the original PMSP published in 2002. This exercise resulted in the following document, which includes critical needs, general conclusions, and tables listing typical activities and efficacies of various management tools for specific pests.

ALASKA

Bill Campbell, Seed Specialist, Alaska Department of Natural Resources, Palmer
Lyall Brasier, Grower, Delta Junction
Tom Jahns, Land Resources District Agent, University of Alaska Fairbanks, Soldotna

IDAHO

Juan Alvarez, Entomologist, University of Idaho, Aberdeen
Ed Bechinski, IPM Coordinator, University of Idaho, Moscow
William Bohl, Extension Educator, University of Idaho Bingham County Extension, Blackfoot
Chris Bryant, Potato Growers of Idaho, Glenn's Ferry
Keith Esplin, Potato Growers of Idaho, Blackfoot
Doug Gross, Grower, Caldwell
Saad Hafez, Nematologist, University of Idaho, Parma
Ronda Hirnyck, Pesticide Program Coordinator, University of Idaho, Boise
James Hoff, Potato Growers of Idaho, Idaho Falls
Kelly Hurst, Consultant, Blackfoot
Pamela Hutchinson, Weed Scientist, University of Idaho, Aberdeen
Pat Kole, Idaho Potato Commission, Eagle
Bill Kral, DuPont Crop Protection, Twin Falls
Kelly Luff, Bayer Crop Science, Kimberly
Jeff Miller, Potato Pathologist, University of Idaho, Aberdeen
Jennifer Miller, Northwest Coalition for Alternatives to Pesticides, Boise
Phillip Nolte, Extension Seed Potato Specialist, University of Idaho, Idaho Falls
Nora Olsen, Extension Potato Specialist, University of Idaho, Twin Falls
Richard Toevs, Grower, Aberdeen

OREGON

Silvia I. Rondon, Extension Entomologist, Oregon State University, Hermiston
Philip B. Hamm, Plant Pathologist, Oregon State University, Hermiston
Dan Hane, Potato Production, Oregon State University
Jeff McMorran, Potato Seed Specialist, Oregon State University
Nicholas Davis, Plant Pathologist, Oregon State University

WASHINGTON

Andy Jensen, Washington State Potato Commission, Moses Lake
Dennis Johnson, Plant Pathologist, Washington State University, Pullman

Summary of the Most Critical Needs in Pacific Northwest (PNW) Potato Pest Management

Research

1. Develop comprehensive pest prediction models, reliable sampling methods, and accurate action threshold levels.
2. Develop pest management strategies that lower inputs/costs for growers while maintaining the sustainability of potato production.
3. Investigate the management and impacts of green manures in/on potato cropping systems.
4. Investigate soil microbes and their benefits to pest management; determine what effects fumigants and biological amendments have on the soil microbial community.
5. Research alternatives to chlorpropham (CIPC) for sprout inhibition in stored potatoes.
6. Investigate the interaction of pest management strategies and their effects on pest control and potato crop safety.
7. Develop area-wide management plans for the management of the potato virus Y mosaic complex (PVY).
8. Investigate the biology and interaction of potato pests including new emerging pests.
9. Research powdery scab management.
10. Determine pesticide impacts on beneficial and other non-target organisms.
11. Develop pesticides with different/new modes of action to guard against the development of resistance.
12. Research the management of potato tuberworm and potato cyst nematode.
13. Research the effect of different agronomic practices on pests and their management.

Regulatory

1. Work with EPA in addressing FQPA issues to provide realistic and commonsense risk assessment data in order to avoid the loss or cancellation of pesticides.
2. Allow resistance management and crop rotation practices as a justification for Section 18 labels.
3. Maintain the tolerance for CIPC until a viable economic alternative is available.
4. Regulate and enforce strict seed certification and phytosanitary standards across state and national borders to prevent pests that we do not already have.
5. Encourage Natural Resources Conservation Service (NRCS) to provide cost share money for additional IPM practices.

6. Provide tuberworm traps and monitoring for large-scale studies.
7. Improve communication with NRCS to develop realistic conditions for cost share money.
8. Preserve organophosphate and carbamate chemistries until suitable alternatives for the same pest spectrum are developed.
9. Implement State National Harmonization Program (SNHP) for seed potatoes.

Education

1. Provide accessible, web-based pest management information, including an online clearinghouse for research data.
2. Educate growers about the use of green manures for pest management, including the different types of green manures and which varieties target which pests.
3. Educate the industry and the public about science-based information. (Why are non-conventional crop products so successful?)
4. Educate growers and consultants about interdisciplinary pest management.
5. Increase interdisciplinary pesticide resistance management education for growers, crop advisors, and regulators (e.g., Insecticide and Fungicide Resistance Action Committees).
6. Educate NRCS and growers about how to utilize NRCS money (from all programs, including CSP and EQIP) for pest management.
7. Educate growers about the proper use of pesticides (including appropriate application timing and proper pest identification before application).

Introduction

The Environmental Protection Agency (EPA) has completed the risk assessments required under the Food Quality Protection Act of 1996 (FQPA) and is continuing its pesticide re-registration process. However, with the advent of the FQPA and subsequent risk assessments, several pesticides were voluntarily cancelled or now have reduced or more restrictive label uses.

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 potato-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 great potential to play either a positive or negative role in the pest complex. 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.

Additionally, some of the risk assessments for pesticides used in potato production in the PNW (e.g., aldicarb, metam-based products, and carbofuran) are not finalized, and it is uncertain what changes, if any, will be made to their use patterns.

The total effects of FQPA and ESA are yet to be determined. Clearly, however, new pest management strategies will be required in the industry. 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 emphasis on economically viable solutions; and understanding the impacts of pesticide cumulative risk.

In a proactive effort to identify pest management priorities and lay a foundation for future strategies, potato growers, commodity group representatives, pest control advisors, regulators, environmentalists, university specialists, and other technical experts from Alaska, Idaho, Oregon, and Washington formed a work group and assembled the following document. Members of the group met on January 26, 2006, in Pocatello, Idaho, 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 potato production. The resulting document was reviewed by the workgroup, including members who were not present at the meeting. The final result is this document, which is a comprehensive strategic plan addressing many pest-specific critical needs for the potato industry in the Pacific Northwest states.

The document begins with a region-by-region overview of potato production in the Pacific Northwest states, followed by discussion of critical production aspects of this crop including the basics of Integrated Pest Management (IPM), export issues, pesticide resistance concerns, and genetic modification in potatoes. The remainder of the document is an analysis of pest pressures during the production of potatoes, organized by crop life stages. Key control measures and their alternatives (current and potential) are discussed. Differences between production regions represented are discussed where appropriate.

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

Production of potatoes grown for seed is not covered by this document.

NOTE: 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 does not imply endorsement by the work group or any of the organizations represented.

Production Regions

Idaho

Idaho is consistently ranked first in potato production and acreage in the United States. In 2005, total potato production in Idaho was 118,288,000 cwt, 28% of the total U.S. production. The majority of potato production is adjacent to the Snake River Plain in southern Idaho where water is available for irrigation. Sprinkler irrigation is used on more than 99% of the crop. Major production regions in Idaho include, in order of production volume: southeastern Idaho, eastern Idaho, the Magic Valley, and the Treasure Valley.

Southeastern Idaho

The southeastern Idaho region is comprised of the following counties: Bannock, Bingham, Caribou, Franklin, Oneida, and Power. This area of the state accounted for 32% of potato acreage and 31% of production in Idaho in 2005.

Eastern Idaho

Eastern Idaho includes the following counties: Bonneville, Butte, Clark, Custer, Freemont, Jefferson, Lemhi, Madison, and Teton. This region accounted for 36% of potato acreage and 30% of production in Idaho in 2005.

Magic Valley

The Magic Valley is located in south central Idaho and includes the following counties: Blaine, Cassia, Gooding, Jerome, Lincoln, Minidoka, and Twin Falls. The Magic Valley accounted for 25% of potato acreage and 28% of production in Idaho in 2005.

Treasure Valley

The Treasure Valley, in southwestern Idaho, also reaches into Oregon. It includes the Idaho counties of Ada, Canyon, Elmore, Owyhee, Payette, and Washington, and Malheur County in Oregon. The Idaho counties in this region accounted for 6.5% of Idaho's potato acreage and more than 8% of the state's potato production in 2005.

Washington

Washington State is consistently ranked second in potato production and acreage in the United States. In 2005 total potato production in Washington was 95,480,000 cwt, almost 23% of the total U.S. production. Potatoes are primarily produced in the eastern part of the state in the Columbia Basin and along the Snake River where water is available for irrigation. Sprinkler irrigation is used on approximately 90% of the potatoes grown in the Columbia Basin; furrow and drip irrigation are used on the remainder. Drip irrigation acres are still limited, but benefits of this irrigation method include reduced water use and higher yields.

A small portion of the state's potato crop, mainly fresh market potatoes, is produced on the west side of the Cascade Mountains, in the Skagit Valley and Whatcom County. Potato acres west of the Cascades are not irrigated.

Columbia Basin
Counties in the Columbia Basin of Washington include: Adams, Benton, Franklin, Grant, Kittitas, Klickitat, Lincoln, Walla Walla, and Yakima. The Columbia Basin accounted for 93% of potato acreage and 96% of production in Washington in 2005.

West of the Cascades
Counties west of the Cascades in Washington that produce potatoes are Skagit and Whatcom. This region accounted for 7% of the potato acreage and 4% of production in Washington in 2005.

Oregon
Oregon ranked fifth in the nation for potato production in 2005. Total potato production in Oregon in 2005 was 22,023,000 cwt, more than 5% of the total U.S. production. The vast majority of potato acreage in Oregon is east of the Cascade Mountains, in the Columbia and Klamath River basins and the Treasure Valley. A small amount of production takes place west of the mountains. Seventy percent of Oregon's potato acreage is under center pivot irrigation systems. The remaining acres are irrigated by rill, wheel line, furrow, lateral move, and solid set systems.

Columbia Basin
The Columbia Basin of Oregon includes Baker, Morrow, Umatilla, and Union counties (see also *Columbia Basin* in Washington, above). These four counties, in the northeast portion of the state, accounted for 71% of the potato acreage and 77% of production in Oregon in 2005.

Klamath Basin
The Klamath Basin in south central Oregon includes Crook, Jefferson, and Klamath counties. It accounted for 17% of potato acres and 14% of production in Oregon in 2005.

Treasure Valley
The Oregon portion of the Treasure Valley (see also *Treasure Valley* in Idaho, page 9) is located entirely in Malheur County, which accounted for 10% of the potato acreage and 8% of production in Oregon in 2005.

West of the Cascades
West of the Cascade Mountains in Oregon, potatoes are produced in Multnomah and Washington counties. This region accounted for less than 2% of the potato acreage and less than 1% of production in Oregon in 2005.

Alaska
The commercial production of potatoes in Alaska occurs mainly in the Matanuska-Susitna ("Mat-Su") Valley due to its deep, fertile soils, maritime climate, extended daylight hours during the growing season, and proximity to the major market of Anchorage. The Mat-Su Valley, located in south central Alaska, has 59% of the state's potato acreage and produces 84% of its potatoes. The Delta and Fairbanks regions in the state's interior account for another 38% of the acreage and 15% of the production. Across both growing regions, half of the acres are irrigated, all via sprinklers.

Potato Variety Selection

Historically, potato producers in the Pacific Northwest have relied heavily on a single variety, Russet Burbank, because the market for other varieties was limited. Since the introduction of new russet types and processing varieties in the early 1990s, the historical choice to grow only Russet Burbank has gradually changed. The percentage of the crop planted to Russet Burbank in Idaho, Oregon, and Washington in 2006 was 66, 26, and 35, respectively. Virtually none were planted in Alaska in 2006. Markets have been established for many other types of potatoes.

Many characteristics are considered when choosing a potato variety. Market acceptance and economic advantage are still the major factors, but other considerations include yield potential, conformity to market specifications, availability of information about managing the particular variety, and resistance to common defects, diseases, pests, and stress-related problems (e.g., Russet Burbank stores well; Ranger Russet is resistant to internal defects such as hollow heart, brown center, and net necrosis). Very often the processor with whom a grower has a contract makes the variety selection, based largely upon market demand. Table 1 lists the potato varieties planted in 2006.

Table 1: Percent of potato acreage planted to each potato variety in each state in 2006

	AK	**ID**	**OR**	**WA**	**Usage**
Russet Burbank		66	25.9	34.9	Fresh, frozen processed
Russet Norkotah	40	10.2	20.4	14.0	Fresh
Shepody	20	[1]	13.5	6.9	Frozen processed, fresh (Alaska)
Ranger Russet	5	12.7	22.5	15.9	Frozen processed, fresh (Alaska)
Umatilla			2.2	8.3	Fresh, frozen processed
Alturas		2.2	5.5	3.7	Processing, dehydrated
Cal White	15				Processing, fresh, dehydrated
Green Mountain	5				Fresh
Yukon Gold	5				Fresh
Others	10[2]	8.9[3]	10	16.3	Fresh, processing

[1] Not reported by NASS
[2] "Others" in Alaska includes: Dark Red Norland, Cherry Red, Bake-King, German Butterball, and miscellaneous other varieties.
[3] "Others" in Idaho includes red potatoes

Integrated Pest Management (IPM) in Potatoes

Potato integrated pest management (IPM) programs gained momentum in the 1970s when research and extension faculty in entomology and plant pathology worked with state and other agencies to reduce the incidence of potato leafroll virus (PLRV). The IPM program included insecticide application to dormant peach and apricot trees to kill overwintering eggs of the green peach aphid, the insect that transmits leafroll virus to potatoes. An educational campaign was also developed and implemented to help homeowners understand the threat their backyard peach trees posed to the potato industry. Since that time, IPM has become the standard approach to pest control in potatoes in the region. IPM in potatoes can broadly be defined as an approach to pest management that combines cultural, chemical, and biological control methods, along with action thresholds and field scouting, to effectively keep pest populations below economically damaging levels, often with reduced use of pesticides. Instead of focusing on one particular tactic, potato growers consider all available pest control tools to develop an overall strategy.

Growers use many cultural IPM tactics before or during planting. They include, but are not limited to: rotating crops, using green manures, selecting appropriate fields, assuring adequate soil moisture at planting, selecting appropriate varieties, using certified seed, sanitizing seed-cutting equipment, altering planting dates, and planting at the most appropriate depth. IPM tactics used during the growing season can include: assuring appropriate fertility and irrigation, scouting to determine the level of pest presence, and applying pesticides only when an infestation exceeds economic thresholds. Some of these practices are discussed below.

Crop Rotation

Crop rotation impacts future pest management decisions and plays an important role in the economics of the crop. Rotation is important for soil building and fertility management and is essential for the integrated management of difficult-to-control pests. The inclusion of non-host crops in a rotation can reduce populations of pests that attack potatoes, particularly with increasing years between potato crops. Selecting rotational crops that allow growers to manage weeds, insects, or disease pathogens that are hard to control in the potato crop is an integral part of an IPM strategy. One example of this is using a wheat-sugarbeet-barley-potato rotation to help combat nightshade weeds, which are difficult to control in potatoes since potato and nightshade are closely related. Nightshade species are not as difficult to control in wheat or barley, so this rotation allows potato growers to use herbicides that are more effective at combating nightshades during the years in between potato plantings.

In addition to the selection of the particular rotational crops, the length of rotation is an important factor in pest management. Increased time between potato crops (e.g., 4 to 5 years) helps reduce the severity of *Verticillium dahliae,* Rhizoctonia, scab, silver scurf, and early blight, as well as the incidence of other soil-borne potato pests such as wireworms and nematodes. It is also very useful in the management of Colorado potato beetle.

Crop rotation is also discussed in the *Pre-plant* subsection of the *Pest Pressures and Control Measures by Crop Stage* section, beginning on page 17.

Green Manures

Green manures are those crops that are planted in the fall or early spring after the previous crop has been harvested, but before the potato crop is planted. They are incorporated into the soil before they reach maturity. They can also be considered a rotational crop, since they require management, inputs, and planning (e.g., herbicide and fertilizer applications, irrigation). Green manures improve the physical properties, nutrient profile, and organic matter content of the soil. Research conducted in Idaho has shown that green manure crops have the potential to be a viable method for nematode and disease management. Verticillium wilt (early die) symptoms are significantly reduced with incorporation of the green residues of sudangrass (*Sorghum sudanese*); crops in the Brassicaceae family such as rapeseed, oilseed radish, and mustards; grain crops such as barley, wheat, and corn; and certain other crops. The diseases black dot and Rhizoctonia may also be suppressed.

Certain crops in the family Brassicaceae, namely oilseed radish, mustard, and rapeseed, have also been found to affect nematode populations when used as green manures. These plants produce a class of chemicals called glucosinolates. When these chemicals are released from the plants via chopping and disking, they are hydrolyzed enzymatically in the soil to release many biologically active compounds including isothiocyanates. Some of these compounds have nematicidal and fungicidal activity in the soil. Additionally, they activate natural enemies in the soil, further adding to their pest management utility. Arugula (*Eruca sativa*), some mustards, and other types of green manures may suppress weeds.

Use of green manures is also discussed starting on page 19 within the *Pre-plant* subsection of the *Pest Pressures and Control Measures by Crop Stage* section.

Variety and Seed Selection

Some potato varieties tolerate disease infections better than others. For example, varieties with above-average resistance to Verticillium wilt, such as Alturas, Bannock Russet, Chipeta, Ranger Russet, and Sangre, can be planted in fields with a history of the disease. However, disease resistance does not mean that Verticillium wilt will not impact yield. Ranger Russets are resistant to internal defects and do not express tuber net necrosis, an economically important disease caused by potato leafroll virus (PLRV).

Growers find that the best defenses against potato viruses are planting certified seed, planting varieties that are tolerant to the virus, and locating fields at least ¼ mile away from other potato fields to reduce the spread of viruses between fields. Certified seed is not guaranteed to be free of virus; however, it will likely have low levels of infection and production of a commercial potato crop will be unaffected. Growers take great care to make sure they know the virus level of any seed lot purchased. During the rotational period, use of certified seed for small grain and other crops can reduce weed infestations in the potato crop.

IPM Practices in the PNW

Below is a checklist of IPM practices that are employed by potato growers in Alaska, Idaho, Oregon, and Washington. Some of the practices are important for the management of specific pests or types of pests (e.g., diseases), whereas others are beneficial for the management of most or all pests. While it is not possible to use all of these practices simultaneously, growers select those that have a history or the potential for being the most practical, useful, and economical for their farm.

- Use clean field equipment. Clean field equipment between fields to prevent the spread of nematodes.
- Follow a 4-year or longer rotation, where possible.
- Plant certified seed and know the level of virus infection in any seed lot purchased.
- Plant potato varieties for their disease resistance when possible. (Growers may not have control over variety selection.)
- Plant potato varieties that do not express net necrosis when possible. (Growers may not have control over variety selection.)
- Plant and incorporate green manure crops to help manage soil-borne pests.
- Adjust fertility and irrigation practices to manage diseases; high fertility and excessive water encourage disease.
- Keep written notes or field maps about pest problems and pesticide applications.
- Use forecasting models to time fungicide treatments for early and late blight.
- Do not plant potatoes in areas with excessive water (e.g., near the center of the irrigation pivot).
- Destroy cull potatoes to reduce sources of late blight and other diseases and insects.
- Sort off and remove decayed tubers coming into storage.
- Assay fresh-marketed tubers going into storage for the level of silver scurf to determine if long-term storage is feasible.
- Take soil samples to detect the presence of nematodes and wireworms.
- Choose rotational crops that compete well with weeds, are non-hosts for diseases, insects, and weeds, and allow the control of problematic pests.
- Apply pesticides in rotational crops for pests such as wireworms that are difficult to control in potatoes.
- Control weeds in rotational crops that are alternate hosts for potato diseases and insects, such as nightshades.
- Spot-spray weed patches rather than spraying entire fields.
- Adjust herbicide application rates based on weed infestation levels.
- Rotate pesticides to avoid resistance.
- Plant winter cover crops for weed and erosion control.
- Control weeds in fencerows and other areas by growing cover crops.
- Scout fields for insect, disease, and weed problems, and for the presence of beneficial insects. Scout potato fields for weeds to determine need for herbicides. Scout the previous crop for potential weed problems.
- Use economic thresholds to determine need for pesticide applications.
- Harvest early in appropriate cultivars to avoid net necrosis.

Export Issues

As more Pacific Northwest potato products are being exported, managing potential quarantine pests and viruses and ensuring correct use of crop protection or preservation products has become a high priority for the potato industries in each state. Opening a market can take years, so it is vital that only potatoes free of quarantine pests, viruses, and prohibited substances are exported. Although quarantine items differ among the various export markets, several appear on multiple lists.

Nematodes, *especially Columbia Root Knot, Golden, and Potato Cyst Nematode*

- Columbia Root Knot Nematode is present in the Pacific Northwest and is a major focus of prevention efforts in the potato industry.
- Golden nematode is not known to exist in the Pacific Northwest, but surveys for this pest are occasionally undertaken as a preventive measure.
- On April 19, 2006, officials of USDA's Animal and Plant Health Inspection Service (APHIS) and the Idaho State Department of Agriculture (ISDA) announced the detection of potato cyst nematode (PCN), *Globodera pallida*, a major pest of potato crops. This was the first detection of the pest in the United States. The nematode cysts were detected during a routine survey of tare soil at an ISDA grader facility in eastern Idaho. In that survey, more than 35,000 samples were analyzed from across all of Idaho's commercial potato and potato seed production areas, and only one was positive. On August 29, 2006, state and federal officials announced the establishment of a regulatory area near Shelley. The regulated area spans approximately 10,000 acres including approximately 3,500 acres of potatoes. Growers are required to have equipment cleaned and sanitized before they leave the regulated area and before leaving an infested field within the regulated area to help prevent the spread of potato cyst nematode.

Potato Viruses, *including strains of PVY and Potato Mop Top Virus*

- Potato viruses are more of a concern for seed exports than fresh exports, but shipments will be rejected in some markets if testing finds certain viruses present.
- PVY strains and Potato Mop Top Virus are frequent concerns in export markets. The National Potato Council (NPC) and APHIS have recently undertaken a virus management plan.

Crop Preservation/Protection Products

- Frequently, an export market will express concern that exported potatoes could be planted by individuals within the importing country (essentially using a fresh potato as a seed potato), thus spreading diseases. Therefore, effective use of sprout inhibitors is sought to prevent this.
- CIPC is the most commonly used sprout inhibitor, but others exist. Organic options and irradiation have also been explored for sprout inhibition.

Pesticide Harmonization Issues

- While to date most trade challenges have involved quarantine issues, pesticide residues and related issues are emerging as areas of concern for exports. PNW

- Potato growers could apply a pesticide according to the U.S. label and still have a problem abroad because of a more restrictive Maximum Residue Level (MRL) tolerance in the receiving country.
- Several countries are establishing their own "positive MRL" lists. As more of these lists are developed and implemented, growers must be aware of the allowable tolerances.

Pesticide Resistance in Potatoes

Pesticide resistance in potatoes can occur when there is an inherited change in the susceptibility of the pest to the pesticides used. Resistance to a single pesticide compound often means cross-resistance to other chemically related compounds that share a common target site within the pest and a common mode of action. Potato growers in the PNW practice resistance management by consciously rotating among chemical classes and modes of action, even in the rotational crops, and by scouting for the presence of pests so that pesticides are not applied unnecessarily. In order to manage resistance, growers must have a variety of pesticide types available for use in potatoes as well as in their rotation partner crops. In the case of fungicide resistance management, the use of multi-site fungicides helps to reduce the risk of resistance development. Judicious use of tank mixes, utilizing a variety of fungicide types, is another critical component in managing the resistance of disease pathogens to fungicides.

Genetically Modified Potatoes

Genetically modified (GM) potato varieties are not currently being used because such varieties have come into disfavor. There is very low acceptance in the marketplace, both domestically and internationally. Potato varieties that have been genetically modified have the potential to provide effective management alternatives for a number of pest-related problems involving insects, diseases, and weeds.

Colorado potato beetles have previously been managed using genetically modified potatoes. Genetically modified potatoes have also been developed that prevent or reduce damage due to potato leafroll virus and PVY. The mosaic viruses of potato, including strains of PVY and PVA, have proven difficult to manage adequately using current control strategies. Genetically enhanced potato varieties show potential in this area of disease management. Other important disease management issues such as potato late blight and early blight may also be addressed using genetically enhanced potato varieties.

Currently, however, there are barriers to the adoption of genetic enhancement technology. There is a need for research and education regarding the safety and environmental impact of GM potatoes. There is a need to show low risk in terms of environmental impact and effects on non-target organisms.

Pest Pressures and Control Measures by Crop Stage

The remainder of this document is an analysis of pest pressures during the various growth stages of potatoes. Key management practices and their alternatives (current and potential) are discussed. Differences between production regions throughout the Pacific Northwest are discussed where appropriate.

PRE-PLANT

The pre-plant period for any field includes all production seasons since the previous potato crop and the late fall, winter, and early spring just prior to the planting of the potato crop.

The rotation of potatoes with other crops is an integral part of the pre-plant pest management strategy. (Crop rotation is also discussed on page 12.) Rotating to different crops in between potato plantings provides pest control benefits, loosens compacted soil when rotating from cereals with fibrous root systems, adds nitrogen when rotating from a legume crop such as alfalfa or beans, incorporates organic matter when rotating from crops such as small grains and corn, and carries nutrients over when rotating from vegetable or other high-input crops. Although pest management drives many crop rotation decisions, growers also consider crop economics, market forces and availability, and machinery when making final decisions about the crops they include in their rotation.

In southeastern Idaho, a typical rotation is 2 to 5 years and can include grains, alfalfa, corn, canola, and sugarbeets. The longer rotations generally involve alfalfa. Crop rotations in eastern Idaho are much the same as southeastern Idaho, except that sugarbeets are not a typical rotation crop. Crop rotations in the Magic Valley of Idaho and the Treasure Valley of Idaho and Oregon last from 3 to 7 years and can include grains, alfalfa, corn, canola, sugarbeets, dry beans, peas, and green manure crops. The Treasure Valley has the luxury of being able to add seed crops (e.g., sweet corn, alfalfa, clover), mint, and onions to the rotation. In the Columbia Basin of Oregon and Washington, rotations last 3 to 7 years and include grasses, wheat, corn, alfalfa, and miscellaneous vegetable crops. West of the Cascades in both Oregon and Washington, rotations last 2 to 4 years and include wheat, grass grown for seed, corn, and various vegetable crops. In the Klamath Basin of Oregon, potato/grain rotations are decreasing as alfalfa and green manures are added into the rotation. Rotations with alfalfa and grains can last 6 years. In Alaska, a common rotation would consist of potato, vegetable (i.e., lettuce or cabbage), and fallow or grain.

Evaluating a field's history is an important part of field selection and pest management during the pre-plant period. In particular, growers consider the cropping history of the field, previous pest populations, and pesticide use practices.

The cropping history of the field influences potato production and pest management in a number of ways. Sugarbeets, for example, can increase soil compaction; following sugarbeets with potatoes can potentially leading to lower potato yields and quality.

Wireworms may be a problem when the field was previously cropped to grass sod, pasture, wheat, corn, cereals, alfalfa, beans, onions, or was fallow ground or ground not farmed for more than one year.

In evaluating the pest history of a field, growers gather information on the presence of nematodes, wireworms, and problem weeds such as nightshade and field bindweed in previous crops.

The history of pesticides, particularly the herbicides, used in a particular field is also important, as some chemicals are persistent enough in the soil to cause residual impacts on the subsequent crop. For instance, the herbicides imazamethabenz-methyl (Assert) or flucarbazone-sodium (Everest) used in small grains can damage a potato crop planted in the same field the next year. Conversely, rimsulfuron (Matrix) used in potatoes can result in sugarbeet, onion, or barley crop injury the following season. Herbicide carry-over is exacerbated by the semi-arid soils and short growing seasons present in some parts of the PNW; herbicides that would typically degrade under average conditions can persist longer under these conditions, resulting in injury to the following crop. Drought further extends the persistence of some herbicides in the soil.

Taking cropping history, pest population history, and pesticide use history into consideration at pre-plant, growers may find it necessary to choose another field for planting potatoes or to delay introducing potatoes into the rotation until more favorable conditions exist.

Soil sampling and analysis determines soil fertility, chemistry, and physical characteristics. Fertilizer applications are made at the pre-plant stage. Verticillium levels can be detected through sampling, which can aid in disease management decisions. While it is possible to sample for wireworms, very few growers do this. It is impractical, and no correlation between the number of positive samples and damage has been found. To determine wireworm populations, growers rely on the field's history of wireworm damage. They avoid planting potatoes in fields with a history of high wireworm damage, or they apply soil insecticides to control wireworms.

Tillage operations and fall bedding also occur during this crop stage. Fall bedding occurs after a wheat harvest and involves marking and hilling (forming rows) a field where potatoes will be grown the next spring to create beds. Primary tillage incorporates residue from the previous crop, reduces wheel traffic compaction from the previous season, improves water filtration and soil aeration, controls weeds and nematodes, loosens the soil for root penetration, and provides a suitable seedbed. Fall bedding is not practiced in the Columbia Basin.

Irrigation late summer to early fall to can help to germinate volunteer weed seeds. It also helps growers get a good sample for nematode analysis, as increased moisture in the soil increases nematode egg hatch.

Some chemical controls are applied in the fall or spring prior to planting a potato crop. Herbicides are used to control weeds that escape control in rotational crops. Soil fumigation is most commonly used in the fall to control nematodes, diseases such as Verticillium wilt, and sometimes weeds. Fumigation is scheduled to take advantage of optimum soil temperatures, to target the most susceptible stage of pests, to increase exposure time of nematicides, and to avoid the persistence of damaging fumigant residues at planting. Fall fumigation, in contrast to spring fumigation, allows for timely planting of the spring crop. Spring fumigation must wait for sufficiently warm soil temperatures, thereby postponing planting. For long-season cultivars, fall fumigation is a necessity. Ninety percent of the potato acres in Washington are fumigated, 82% of the potato acres in Oregon are fumigated, and 50% of the Idaho potato acres are fumigated. Fumigation is not practiced in potatoes in Alaska.

Green Manures

Green manures, which are defined and discussed on page 13 in the *Integrated Pest Management* section, are an important consideration in potatoes during the pre-plant stage. Green manure crops can be planted during the fall of the year prior to planting potatoes to aid in pest management and to improve soil quality. However, in Alaska, as well as in some parts of Idaho and Washington, it is too cold for fall-planted green manures to be effective.

Green manures usually fit into potato cropping systems where potatoes follow small grains. They can be planted after grain harvest in late summer or early fall, even in some short season areas. The earlier the planting, the better, to allow for sufficient biomass production. These crops usually require 8 to 10 weeks of soil temperatures above 60ºF for adequate growth; therefore, growers seed green manure crops no later than August 15 to 30, depending on location. With the advent of earlier maturing oil radish varieties, the length of the necessary growing period may be shortened.

Green manures can be conveniently planted by drilling, spreading with bulk dry fertilizer, or even by aerially seeding. When harvesting the grain crop, a chaff spreader may be needed on the combine to avoid creating chaff rows that hinder green manure soil-to-seed contact and plant establishment. If the standing grain stubble is left for later incorporation with the green manure crop, volunteer grain emergence may be reduced and nitrogen immobilized by the straw. This can result in decreased winter leaching and decreased need for additional nitrogen.

To obtain maximum benefits, green manure crops are managed as carefully as crops that will be marketed. They require planning, irrigation, and inputs such as herbicides and fertilizer. If a green manure crop is stressed due to lack of nutrients, weed competition, too much or too little water, or other negative influences, biomass production is reduced. In planting green manures, growers sometimes pre-irrigate to germinate weed seeds, including volunteers from previous crops. In fields with known nematode problems, growers kill volunteer cereals using tillage or herbicide application to prevent host plants from growing, and they apply appropriate herbicide treatments when necessary to control other problem weeds. Otherwise, volunteer grain and weed control management is implemented after green manure crop emergence. As with other crops it is important to plant at the appropriate seeding rate so that complete canopy coverage can occur as fast as possible and the green manure can out-compete the weeds.

Green manure is chopped and then disked under to incorporate the green foliage and the roots into the soil. Disking without chopping results in uneven distribution of the green manure biomass and is therefore not practiced. Glucosinolate-producing green manures are chopped very thoroughly in order to disrupt the plant cells and release the glucosinolates. They are disked immediately after chopping to assure minimal glucosinolate loss. Some research indicates that glucosinolate-producing green manures should be incorporated before a hard frost (below approximately 25°F), since low temperatures cause an undesirable disruption to plant cells that diminishes the biopesticide compounds in the plant. To prevent seed production, mustard green manure crops may be incorporated into the soil at the pod formation stage. After incorporation of green manures, soil should not be allowed to dry out since this will inhibit breakdown of the incorporated green manure crop.

Mustard seed meal as a by-product of biofuel production has been shown to have many desirable and highly effective green manure characteristics. As bio-fuel production plants become more prevalent in potato production areas, seed meal will become more available and convenient to use.

Critical Needs for Management of Green Manures in PNW Potatoes Pre-plant

Research

- Identify frost- and drought-resistant types and blends of green manures that can be utilized effectively in potato production areas with short growing seasons.
- Evaluate standard and new green manure types for activity on specific pests, especially weeds and some insects, since not much information is available on these pests in the PNW.
- Determine best management practices (BMPs), such as pre-planting options; seeding methods; fertilizer, irrigation, and pest management methods; effective soil incorporation methods; and time management, particularly in potato production areas where this type of research has not been done.
- Targeting these same areas, determine input costs of growing green manures and short- and long-term benefits or returns to the following potato crop, as well as to the entire potato cropping system.

Regulatory

- Hasten registration of new herbicides and label expansion of existing herbicides for weed control in green manure production.

Education

- Develop a working relationship with other entities interested in the use of green manures in cropping systems such as Native American Tribes, Soil Conservation Districts, Natural Resources Conservation Service (NRCS), and grower and commodity groups.
- Educate growers about the specific green manure types and blends and the importance of green manure choice on a field-by-field basis.

- Increase grower education concerning BMPs for green manure production as well as the benefits of green manures in potato cropping systems.
- Distribute available information pertaining to the use of green manures in potato cropping systems.

Nematodes

Nematodes are one of the major limiting factors for potato production in the Pacific Northwest. Nematode infestation primarily reduces quality but can also reduce yields, in either case contributing to economic loss. Predominant nematode pests identified in the rhizosphere (the soil zone that surrounds and is influenced by the roots of plants) of potatoes are root-knot nematodes (*Meloidogyne* spp.), root-lesion nematodes (*Pratylenchus* spp.), stubby-root nematodes (*Trichodorus* and *Paratrichodorus* spp.), and potato-rot nematodes (*Ditylenchus destructor*). Nematodes are of concern to growers not only because of their feeding damage but also their role in some economically important potato diseases. For example, there is a relationship between the feeding of one species of root-lesion nematode and early die/Verticillium wilt infection (*Verticillium dahliae*). And while stubby-root nematodes do not cause direct damage in potatoes, they are vectors of tobacco rattle virus (TRV), which causes corky ringspot in potatoes.

Cultural practices for nematode control include reduction of crop residue through tillage and avoiding rotation crops and weeds that may promote increased nematode population levels. For example, root-knot nematodes have a wide host range that includes alfalfa and wheat, both of which are common rotational crops.

Weed control is employed before and during potato culture, because nematodes have many weed hosts and are able to move to the crop quickly. Potato growers sample for the presence of nematodes before any treatment or management decision is made and before planting. The best time for nematode sampling is usually before harvest (early fall in the Pacific Northwest) in fields of rotation crops that precede potatoes. Since the distribution of nematodes is seldom uniform, potato growers subdivide and map the field to be sampled. Soil samples are taken from the plant root zone, and plant samples are also taken from areas in the field showing symptoms. Analysis of soil samples, as well as knowledge of field history, is used to determine nematode population levels. Growers may choose potato varieties for particular fields in part based on nematode population levels. If the field history or soil samples indicate the presence of root-knot nematodes, for example, growers are restricted to early-harvest varieties such as Russet Norkotah or Shepody. Harvesting early reduces root-knot nematode symptoms on the tuber. There are also some potato varieties that show good tolerance to Tobacco Rattle Virus (TRV), transmitted by stubby-root nematodes. For instance, Gemstar does not exhibit TRV symptoms.

In non-infested fields, growers work very hard to prevent the introduction of nematodes by using clean field equipment, planting clean seed that is certified nematode-free, and avoiding the use of runoff water from other locations to irrigate fields.

Planting a green manure crop before potatoes is an effective way to manage nematodes. Choosing the appropriate variety of green manure is important, because resistance level varies among the different varieties of oil radish and white mustard. Green manure crops of oil radish result in the decline of *Pratylenchus neglectus* population densities, a root-lesion nematode. Likewise, populations of root-knot nematodes were reduced after planting oil radish and rapeseed cultivars, with the lowest populations resulting from the use of oil radish.

When nematode population densities exceed the economic threshold, most growers apply chemical nematicides. Two classes of chemical nematicides are available: fumigants and non-fumigants.

Fumigants are volatile chemicals, which, under typical field conditions, exist as gases or are converted into gases upon interaction with soil water. They are distributed through the soil principally as vapors. Within the fumigant class of nematicides, there are true fumigants and non-true fumigants. True fumigants are nematicides that are injected into the soil as gases or liquids. Those used in potato production in the Pacific Northwest are 1,3-dichloropropene (Telone II), and 1,3-dichloropropene plus chloropicrin (Telone C-17). Chloropicrin is not a nematicide; it is combined with 1,3-D to help manage diseases, weeds, and soil-borne insects. Telone C-17 is used at a higher rate than Telone II because of the reduction in 1,3-D in the formulation. Telone products are applied by soil shank at a depth of 12–18 inches. As an additional pest control benefit, Telone II is recognized for its ability to help control deep-rooted perennial weeds and soil-inhabiting insect pests in the treatment zone.

Non-true fumigants used in PNW potato production are metam-based, such as metam-sodium (Vapam) and metam-potassium (K-pam). These products release methyl-isothiocyanates (MITC) after application in the soil. They are most often applied through the irrigation system. The more water applied with these products, the deeper into the soil profile they migrate. However, since the majority of soil pathogens and weeds that these products target are in the upper 12 inches of the soil profile, treating much below that level is not beneficial. Metam-based products are contact nematicides; therefore, they are not effective against the nematodes inside the root debris or against stubby-root nematodes, which usually reside deeper in the soil. However new information indicates that shanking this product in a manner similar to Telone II can be effective in reducing nematode numbers. As additional pest control benefits, use of metam-sodium or metam-potassium can help suppress disease-causing organisms such as *Verticillium dahliae* (Verticillium wilt/early die) and can have control impacts on weed seeds and improve the quality and yield of potatoes.

The optimum time for soil fumigation in the Pacific Northwest is in the early fall. Soil temperature and moisture are usually optimum then, and this timing allows the fumigant a long exposure interval prior to spring planting. Fumigants can also be applied in the spring, prior to planting potatoes. Soil moisture is the most important factor for achieving the desired pest management through soil fumigation. The amount of soil moisture has a direct relationship to the movement of fumigant through the soil, and it "conditions" soil pathogens for better control. Excess moisture acts as a vapor barrier to prevent proper movement. Conversely, if not enough soil moisture is present to absorb the fumes, the fumigant escapes from the soil too quickly. A soil moisture content of one-half field capacity in heavier soils and slightly below field capacity in sandy soils is optimal for fumigant efficacy.

Chemigation is more common than shanking in Washington State; it is easier, cheaper, and more effective for nematode control than shanking. However, since metam-based products are also employed against diseases and weeds, and shanking can prove more effective against these pests, growers may elect to apply via shanking rather than chemigation. EPA is currently reviewing all fumigants collectively to develop a soil fumigant risk assessment and re-registration eligibility decision.

Non-fumigant nematicides are nonvolatile compounds that kill the nematodes either by contact action, such as ethoprop (Mocap), or by systemic action like aldicarb (Temik) and oxamyl (Vydate). Ethoprop and aldicarb are the only non-fumigant nematicides applied at pre-plant. Aldicarb can be applied at planting, but since it has a 150-day PHI, some growers (e.g., those in eastern Idaho) apply it pre-plant to gain the extra days needed to meet the PHI. Ethoprop in combination with other nematicides is an effective approach for root-knot and root-lesion nematode management. However it is not effective for stubby-root nematode management. Ethoprop is applied in the spring as a pre-plant treatment, because it has to be incorporated and is applied only once per year. Aldicarb and oxamyl will be discussed in more detail in subsequent crop stages.

Root-knot nematodes (*Meloidogyne* spp.) are of particular concern to the potato industry. Columbia root-knot nematode (*Meloidogyne chitwoodi)* and Northern root-knot nematode (*M. hapla)* are endoparasites found in abundance in many areas, especially in sandy soils. Plants infected with *Meloidogyne* spp. develop knots or galls of varying sizes and shapes on their roots. Typical symptoms include stunting, yellow foliage, wilting in the presence of adequate soil moisture, or general nutrient deficiencies. Severely infected plants also suffer from secondary pathogens that cause roots to rot in the field. Infestation can render tubers unmarketable. When the level of infected tubers exceeds 5%, processors and packers generally reject all potatoes from that field. These nematodes have a wide host range, which includes wheat and alfalfa, leading to population increases when potatoes or other susceptible crops are grown in rotation with potatoes. Soil fumigation with metam-based products (Vapam, K-pam) or 1,3-dichloropropene (Telone II) is the most cost-effective chemical method for controlling root-knot nematode. Ethoprop (Mocap) is often used in combination with soil fumigants for an added measure of control. Generally, Columbia root-knot nematodes cause more damage to potatoes than do northern root-knot nematodes. Therefore, any detectible level of Columbia root-knot nematode warrants pesticide treatment. Growers primarily use a fall-applied fumigant in this case. If the previous crop was not alfalfa or clover and northern root-knot nematode counts are low, a non-fumigant nematicide is used. This treatment occurs at planting and is often followed up with a foliar treatment. If the previous crop was not alfalfa or clover and northern root-knot nematode counts are high, a fall-applied fumigant is used. If the previous crop was alfalfa or clover, a fall-applied fumigant is used regardless of numbers of northern root-knot nematodes.

Root-lesion nematodes (*Pratylenchus* spp.) are endoparasites that feed inside the root system of the potato plant. They are of concern to potato growers because they reduce yields indirectly by weakening and increasing stress on the plants and making them more susceptible to fungal and bacterial diseases. Of the 15 species of root-lesion nematodes that attack potatoes, *Pratylenchus penetrans*, and to a much lesser degree *P. neglectus,* are of most concern to growers in the Pacific Northwest. *P. penetrans* has also been shown to increase the susceptibility of potato plants to potato early die.

Planting an oil radish green manure crop before potatoes is an effective way to reduce the densities of *P. neglectus* and to increase tuber yields. Fumigation with a metam-based product (Vapam, K-pam), or with 1,3-dichloropropene (Telone II) is usually effective against lesion nematodes. If there is a field history of early die, field treatment with a fumigant or a non-fumigant is warranted when root-lesion nematodes are detected at all. If there is no field history of early die, higher numbers of nematodes can be tolerated before a field is treated with a non-fumigant nematicide.

Stubby-root nematode (*Paratrichodorus* spp.) feeding injury is not economically important and is rarely visible. Stubby-root nematodes are economically important pests because they vector the tobacco rattle virus (TRV). Corky ringspot disease is a symptom of TRV. Disease incidence in tubers can range from 6 to 55% and leads to complete crop rejection. Growers in Washington State are having more problems with stubby-root nematodes in recent years.

Stubby-root nematodes are easily controlled, but understanding their mobility in the soil is the key. This nematode is highly sensitive to change in soil moisture and temperature. Fluctuation in these two factors causes the nematode to move up and down in the soil profile. Stubby-root nematodes can reside at soil depths of more than 40 inches. When these nematodes migrate deep in the soil profile, they are difficult to control with a fumigant such as 1,3-dichloropropene (Telone II), and it must be used at high rates, thereby increasing costs. For the same reason, contact nematicides such as ethoprop (Mocap) and metam-based products (Vapam, K-pam), are not very effective. Application of aldicarb (Temik) is an effective tool in managing stubby-root nematodes in shorter season areas. More detail on this is provided in the *Planting* section.

If there is a field history of corky ringspot (or TRV), the field must be treated with a fumigant or non-fumigant, regardless of whether stubby root nematodes are detected prior to the potato crop. If there is no field history of corky ringspot or TRV, higher numbers of stubby root nematodes can be tolerated before the field is treated with a non-fumigant nematicide. This is generally aldicarb or aldicarb coupled with oxamyl (Vydate). There is always risk of TRV if stubby-root nematodes are present, even without a history of this disease.

Potato-rot nematodes (*Ditylenchus destructor*) are important because of interactions with secondary organisms rather than because of direct feeding injury. The feeding habit of the potato-rot nematode allows entry of many common pathogenic fungi and bacteria into the tuber. The resulting rot problems can become destructive to an otherwise healthy crop of potatoes. Potato-rot nematodes are not currently present in the Pacific Northwest states. Their host range includes snap beans, red clover, and corn. Alfalfa and oats are not hosts. Potato-rot nematodes can live their entire life cycles within a potato tuber. They mainly feed on underground stem parts and are well able to parasitize growing and stored tubers under most climatic conditions. The nematodes enter potato tubers through lenticles (pores) on the skin near eyes. Nematodes at first exist singly or in small numbers in the tissue just beneath the skin of the tubers, and small, white lesions are present during early and mid season tuber formation. Spread of the nematodes is usually through infected seed, on fungi, or on weed hosts. In cases of severe infestation the lesions coalesce, and the affected tissue darkens gradually through a grayish to a dark brown color. The tuber skin may remain intact but exists as a papery thin membrane over the lesions or may crack as a result of stress in the tuber. Affected tissues are soft and mealy. The effect of nematodes will manifest itself at harvest or storage when infected tubers rot. The best way to control potato-rot nematodes is to prevent their introduction into the field. Use of healthy seed material is the primary step to avoid infestation with *D. destructor*, which has a wide host range. Historically, crop rotation has not been considered part of management of this pest, but it has proven effective when used in combination with sanitary procedures and the use of labeled nematicides on the rotation crop. No green manure crops are effective at reducing potato-rot nematode numbers. Fumigation for other nematode species is an effective way to manage for potato-rot nematodes.

Potato cyst nematode (*Globodera pallida*) was discovered in the United States for the first time on April 19, 2006, after the meeting of the work group to develop this document. Potatoes and tomatoes are the principal crops of economic importance attacked by potato cyst nematode. Damaging populations of the nematode develop when potatoes follow potatoes. Other plants in the Solanaceae family, such as nightshade, could also be hosts for the potato cyst nematode. Potato cyst nematode is a soil-borne organism and does NOT infect potato tubers or seed. Consequently, the primary means of spread of potato cyst nematodes is by cysts being transported in soil on farming equipment, by infested soil adhering to seed potatoes, and in tare dirt. Spreading of potato cyst nematode via seed would only occur if infested soil adhered to the seed tubers. Increased nematode populations increase the risk of spread.

Once a farm is known to have potato cyst nematode contamination, every precaution must be taken to prevent soil movement from the infested land. All farming equipment used on infested land must be pressure washed to remove all soil. All farms or businesses that are a potential source of potato cyst nematode spread must be under state/federal compliance agreements. Types of regulated businesses include potato farms, potato processing and packing facilities, used farm equipment dealers, custom fertilizer applicators, and businesses such as utility companies or surveyors that perform work on infested land. Anyone entering a property where potato cyst nematode is known to occur or is suspected to exist must wear disposable plastic boots or must clean and disinfect footwear. Vehicles or equipment used on land where potato cyst nematode is known or suspected to exist must be power washed with a single-orifice nozzle to remove all soil. Any equipment with inaccessible areas that cannot be guaranteed to be free from soil must be treated using a steam heat treatment.

To date, no chemical controls have been used or recommended to combat the potato cyst nematode.

The Idaho State Department of Agriculture (ISDA) and the United States Department of Agriculture (USDA) have agreed on a program to treat the fields that tested positive for potato cyst nematode. The positive fields are under federal restrictions (no more potatoes are to be planted, no soil is to leave, and equipment is to be cleaned). A surrounding regulated area is restricted in terms of the movement of soil and other articles that could spread potato cyst nematode. The program also includes: extensive soil surveys to determine population levels, fumigation with methyl bromide, planting and incorporation of a cover crop, and post incorporation sampling for up to two cycles per year. This program, which completely excludes potatoes from the infested fields, is expected to last up to 6 years.

Critical Needs for Management of Nematodes in PNW Potatoes Pre-plant

Research

- Evaluate application rates of fumigants.
- Determine efficacy of fumigant combinations.
- Continue new pesticide development work, including fosthiazate.
- Conduct extensive agronomic studies on the use of green manure crops, seeding rates and varieties, planting dates, fertilizer requirements, irrigation, and incorporation of residue.
- Evaluate interaction of stubby-root nematode vector and its host plants (weeds and rotational crops) with regard to the transmission of tobacco rattle virus (leading to corky ringspot disease) in potatoes.
- Investigate the effect of the potential interaction of Verticillium wilt and root-lesion nematodes, *Pratylenchus neglectus* and *P. penetrans,* on potatoes.
- Investigate varying rates of 1,3-dichloropropene (Telone II) fumigant with the intent to document efficacy at lower rates than currently recommended.
- Identify nematode-resistant varieties of rotational crops.
- Develop nematode-resistant varieties of potatoes.
- Develop rapid and accurate identification methods for nematodes.
- Establish better nematode sampling techniques based on soil structure, temperature, and moisture.
- Investigate bio-based control options.
  - Determine impact, agronomics, and economics of oilseed meal on nematodes when used as a biopesticide.
  - Determine importance of bio-competition associated with beneficial free-living nematodes.
- Develop uniform nematode control standards for the entire PNW.

Regulatory

- Hasten registration of new pesticides, including fosthiazate.

Education

- Develop a comprehensive PNW nematode website.
- Increase grower education concerning the importance and cost-effectiveness of pre-fumigation irrigation.
- Distribute available information pertaining to the use of non-composted manures for nematode management.
- Educate growers about the specific varieties of green manure and/or biofumigants for managing specific nematodes.

Diseases

The primary disease organisms that are important in the pre-plant phase are those that are endemic to soils in which potatoes are produced. These are mainly fungal and bacterial pathogens that infect potato plants during growth and harvest.

Key soil-borne diseases include **early die/Verticillium wilt** *(Verticillium dahliae)*, **early blight** *(Alternaria solani*, *A. alternata),* **pink rot** *(Phytophthora erythroseptica)*, **Pythium leak** *(Pythium* spp., usually *P. debaryanum* or *P. ultimum)*, **common scab** *(Streptomyces scabies)*, **powdery scab** (*Spongospora subterranea* subsp. *subterranea*), **black dot** (*Colletotrichum coccodes*), **Rhizoctonia**, **white mold** *(Sclerotinia sclerotiorum)*, **Fusarium dry rot** (*F. sambucinum* or *F. coeruleum* fungi), **soft rot** (*Erwinia carotovora*), and **tobacco rattle virus** (TRV, which causes **corky ringspot**; this virus is nematode-vectored and thus acts like a soil-borne disease).

Crop rotation is important in controlling most soil-borne diseases. Rotating with non-host species can dramatically reduce the inoculum level of most soil-borne disease organisms and increase the populations of organisms antagonistic to soil-borne pathogens. Grass and legume crops are especially effective at reducing soil inoculum. Other important disease-control practices include control of volunteer potatoes and elimination of potato cull piles. Some green manure crops such as Sudangrass or mustards, planted eight weeks before a killing frost to allow for sufficient biomass production, provide partial control of soil-borne diseases through biofumigation and improvement of microbial fauna.

Partial control of soil-borne diseases is achieved through proper tillage. Fall soil preparation and pre-bedding reduce compaction and its associated root health problems and encourage breakdown of plant residues that may harbor some disease organisms. With sandy soils, growers leave some plant residues on the soil surface to prevent soil erosion. In this case, fall tillage is minimal. In Washington, most fields with sandy soil are worked each fall and planted to a cover crop such as wheat or to a green manure such as mustard.

Soil sampling can be used to detect levels of *Verticillium dahliae* (Verticillium wilt/early die) or stubby-root nematodes (vectors of TRV, leading to corky ringspot) to determine whether fumigation is warranted (or, after the fact, to determine if fumigation successfully reduced numbers).

Fumigation is an effective chemical control method for many soil-borne diseases. Fumigants are volatile chemicals that under typical field conditions exist as gases or are converted into gases upon interaction with soil water. They are distributed through the soil principally as vapors. The most common fumigants used for disease control in PNW potato production are metam-based products (Vapam, K-pam), 1,3-dichloropropene (Telone II), and 1,3-dichloropropene plus chloropicrin (Telone C-17). Applications are made by chemigation (metam-based products only), shanking (a broadcast application at 12-18 inches deep in the soil), or chisel plow (a shallow shank). While 1,3-dichloropropene does not control disease, it is an extremely important chemical at this crop stage; when used with metam sodium, it results in better control of soil-borne diseases at reduced rates. It also controls stubby-root nematodes, thereby controlling TRV/corky ringspot.

As stated in the *Nematode* section, above, the optimum time for soil fumigation in the Pacific Northwest is in the early fall.

Aldicarb (Temik), a non-fumigant nematicide, is used to control root-lesion nematodes, which in turn helps suppress Verticillium wilt, and to control stubby-root nematode, which vectors TRV and can lead to corky ringspot. Temik now has a 150-day PHI, restricting its use. It can be applied up to 2 weeks prior to planting in the mark-out process, but can also be applied in furrow at planting.

Critical Needs for Management of Diseases in PNW Potatoes Pre-plant

Research

- Conduct definitive studies on the short- and long-term effects of fumigation (single or repeated applications) on the total bio-population in soil, including the impact on non-target soil microbes. Document interactions and measure the balance between risks and benefits.
- Investigate the correlation between soil bio-populations and disease development.
- Continue to conduct interdisciplinary research on the efficacy of cover crops, including green manures.
- Identify new varieties of green manures for short-season areas, including green manures that can overwinter.
- Identify sources of long-term funding for green manure research.
- Continue to conduct interdisciplinary research on the efficacy of animal manures.
- Continue research on the relative importance of seed-borne vs. soil-borne inoculum for soil-borne diseases Verticillium, black dot, soft rot, and dry rot.
- Investigate recommended rates of 1,3-dichloropropene (Telone II) fumigant with the intent to document efficacy at lower rates.
- Identify new chemical, biological, and cultural controls for soil-borne diseases such as pink rot and powdery scab.
- Devise soil sampling strategies to assess pathogen populations in the soil and establish useable thresholds for treatment.
- Discover new technologies for soil sampling—more credible measures.
- Investigate presence, damage, and control of powdery scab.
- Continue plant breeding programs for host plant resistance.

- Investigate methods for improved detection and management of seed-borne viruses and bacterial ring rot.

Regulatory

- Implement strong quarantine measures to keep out pathogens not yet established here.
- Implement aggressive surveillance to support quarantines.
- Have public institutions (e.g., IR-4) carry more of the burden of obtaining new pesticide registrations to supplement and accelerate the process.
- Improve the process for obtaining Section 18 registrations.
- Strengthen and standardize rules for seed certification.
- Enforce rule to plant certified seed (ID, OR).

Education

- Educate regulators, growers, and industry about pest resistance problems and issues.
- Educate farm workers on use of fumigants to improve application safety.
- Construct a website with pest and pest management information to increase the availability of appropriate information.
- Educate growers on the economic and biological value of using green manures.
- Educate growers about the label (new regulations).
- Continue to educate industry on new research that has been done.

Insects

Wireworms are the major insect concern in Pacific Northwest potatoes at the pre-plant crop stage, and they are increasing in importance. One of the possible reasons for this is the increased rotation with corn for the cattle industry. Further, certain crops grown in rotation with potatoes (e.g., cereals) also are wireworm host plants and therefore increase infestation levels. There are 885 species of wireworms (Elateridae) in the United States. Three commonly damage potatoes in the West: the sugarbeet wireworm, the Pacific Coast wireworm, and the Great Basin wireworm. The sugarbeet wireworm, *Limonius californicus,* and the Pacific Coast wireworm, *L. canus,* are found in soils that have been under irrigation for 3 or more years. The Great Basin wireworm, *Ctenicera pruinina,* infests soils previously dryland farmed, in pasture, or soils recently brought under cultivation.

Wireworm larvae feed on potato seed pieces and underground stems during the spring. The early feeding opens the seed pieces and stems to rotting organisms (fungi and bacteria), which results in poor or weak stands. More serious damage occurs on developing tubers later in the season. In the processing industry, there is a zero tolerance for the presence of wireworm in the raw product, because the hard body of this insect is classified as foreign material. This situation, combined with the fact that there are few effective control measures, makes wireworm a difficult pest to manage.

The life cycle of our most common wireworms requires 3 to 4 years to complete under favorable conditions, and larvae cause the most severe feeding damage during their second and third years.

Wireworms spend the winter in the soil either as partially grown larvae or as new adults. Adults work their way up to the soil surface in the spring when soil temperatures are 55°F or above. These adults (called click beetles) require little or no food and cause no economic damage. The female mates soon after emerging from the soil, then burrows back into the soil to lay eggs in several locations at depths of 1 to several inches. Infestations are often spotty, because oviposition is not uniform and some localities are more favorable for larval development than others.

In the spring when soil temperatures are 50°F or above, the larvae move toward the soil surface from overwintering depths of 6 to 24 inches. When soil surface temperatures reach 80°F or higher, they move downward again. In irrigated fields with complete foliage cover, the soil may remain below this temperature. During the third or fourth season, mature larvae transform to fragile pupae in earthen cells. In 3 to 4 weeks the pupae change to adults, which remain in the soil until the following spring. Wireworms in all stages may be present during any growing season. Because the female click beetles fly very little, infestations do not spread rapidly from field to field.

Because wireworm populations are spotty and erratic, there are no reliable economic thresholds. The most accurate way to assess the need for control is to look at historical problems with wireworms in potato fields. If past crops in a field have sustained economic damage, there may be a need to treat. USDA standards for U.S. No. 1, U.S. Commercial, and U.S. No. 2 potatoes allow only 6 percent external defects. This includes soil or other foreign matter, sunburn, greening, growth cracks, air cracks, scab, Rhizoctonia, and mechanical damage, as well as insect damage. If a reasonable allowance is made for defects other than wireworm damage, the limit for wireworm damage is less than 4 percent.

The need for control should be estimated based on past occurrence of total external defects. If there is no field history available, wireworm baiting in the field can give a rough indication of the need for control. Wireworm baiting gives a poor estimate of population size but is a quick way to determine if wireworms are present. If wireworms are found in baits, treatment is justified. Soil can be sampled to estimate the population density by taking soil cores in different places and extrapolating the wireworm density, but this process is so labor-intensive that few growers practice it. Furthermore, no method consistently predicts the extent of damage caused by wireworms at the end of the season when tubers are harvested.

Certain cultural control practices can effectively reduce wireworm populations. One practice is to avoid rotations that include clovers and grasses. Alfalfa in the rotation is especially effective for reducing wireworms. Because soil dryness can kill many wireworms in an infested field, fallowing a field will reduce wireworm numbers, but the control achieved must be weighed against the income lost from missing a crop year.

Pupae cases can be broken up by plowing a dry field during the first 10 days of August. (Timing will vary slightly by region.)

Avoidance may be a viable alternative for preventing losses to wireworms. If wireworm populations are high, it may be necessary to avoid planting potatoes in a particular field.

Most of the insecticides used to control wireworms are relatively old, and many others have been removed from the market. The elimination of insecticides with long residual soil activity is thought to be one reason for recent increases in wireworm problems. Wireworms can be controlled by broadcast or band treatments of insecticides, by fumigation, or with seed treatments. Broadcast insecticide applications and fumigation are done pre-plant. Band and seed treatments are done at planting and will be detailed in the following section. Usually, controlling wireworms in one crop of a 2- to 4-year rotation will reduce wireworm damage in the other crops.

A few insecticides are labeled for control of wireworm, but no chemical alone can clean up a heavily infested field; rather, combinations of insecticides and fumigants may be required. Even the best insecticides will not kill all wireworms, and a small percentage of a large population can still cause economic damage.

Some insecticides labeled for wireworm control at pre-plant:

Ethoprop (Mocap) can be effective against wireworms and also has nematicidal activity. Applied in the spring as a pre-plant broadcast application, Ethoprop is then incorporated to a depth of 4 to 6 inches. It can be applied only once per year and has proven to occasionally lack efficacy at some locations in Idaho.

1,3-dichloropropene (Telone II), a fumigant, is effective on wireworms that are present at the time of fumigation and within the zone of fumigation. Therefore, it is more effective if applied in early fall or when the soil warms in the spring. It is important that Telone II be applied when soil temperature is 50°F (or higher) or prior to the movement of wireworms down the soil profile and out of the fumigation zone. 1,3-dichloropropene may be used to control high wireworm populations, but a combination of broadcast and band treatments may be more economical to use, depending on the pest complex.

All of the chemicals registered for wireworm control are for use pre-plant or at planting. The effectiveness of the insecticides and fumigants wears off by the time the larvae are most active, which is at the end of the season.

Green peach aphids can be managed at this stage by controlling weeds in prior crops, including volunteer potatoes, nightshades, mustards, and ground cherries, with herbicides, because early infestations of aphids commonly occur on several of these weeds. Winged aphids produced on these weeds later infest crop plants, including potatoes.

Pressure by **Colorado potato beetles** can be reduced by both physical and spatial crop rotations. The beetles are weak fliers and have difficulty flying out of foliage that is more than a few inches high. Additionally, when overwintering adults emerge from the ground in the spring, they have a load of fertilized eggs from the previous year and are ready to start distributing the eggs in new potato fields. The flying muscles of adults are not strong enough to fly long distances, and they need to feed in order to acquire the needed strength. Spatial rotation, or locating potato fields at least 400 meters away from a previous years' field, reduces emerging insects' survival, because they will likely not have the strength to fly far enough to infest the new plants.

Potato growers in Alaska occasionally experience minor **cutworm** infestations. Some growers practice pre-plant irrigation to bring cutworms to the surface. This is followed by a tillage operation for control. No chemical control has been required to date.

Critical Needs for Management of Insects in PNW Potatoes Pre-plant

Research

- Improve sampling techniques to increase cost effectiveness and reliability of wireworm detection. The method must provide sufficient data in the spring, when control measures can be applied, to be of use in making control decisions.
- Research methods to attract and kill wireworm adults.
- Investigate the effect of crop rotations and cover crops and green manures on wireworm populations.
- Investigate the biology of wireworms in potatoes.
- Develop potato varieties resistant to wireworms
- Pesticide testing:
    - More development, research, and new product testing. Products for wireworm control in potatoes are considered minor use; therefore, there is little interest by agrochemical companies for product development. Much of this will need to be public work.
    - Evaluate new chemistries, specifically Fipronil. Increase IR-4 involvement with new potato insecticide registrations.

Regulatory

- Implement strong quarantine measures to keep out insects not yet established here.

Education

- Educate regulators concerning the seriousness of wireworm control issues.
- Educate field staff and producers concerning all elements of control: detection, chemical efficacy, proper timing, etc.
- Educate agrochemical dealers and consultants concerning the selection of appropriate pest management practices.

Weeds

Most growers plan their weed control and herbicide programs for the current potato crop before planting based on field history, crop rotation plans, scouting, and potato variety selection. Fall irrigation accompanied by tillage or a chemical control eliminates most volunteer crop plants and kills some endemic weeds. Some pre-plant spring tillage, even if minimal, also provides control of early-emerging weeds, such as **kochia**. One important weed control measure employed pre-plant is the use of best weed control practices in all rotation and cover crops. This effectively reduces the seed bank for most weeds. Most growers wait to apply herbicides preemergence to potatoes or postemergence at lay-by or last final hilling.

Currently, all the herbicides labeled for use in potatoes regardless of application timing are as follows: for control of most **broadleaf weeds** and some **grassy weeds**, growers look to dimethenamid-p (Outlook), EPTC (Eptam), flumioxazin (Chateau), s-metolachlor (Dual Magnum/Dual II Magnum), metolachlor (Stalwart), metribuzin (Sencor), rimsulfuron (Matrix), and trifluralin (Treflan HFP), except in Alaska where cold soils reduce degradation of some of these products. For **grass** control, sethoxydim (Poast Plus) and clethodim (Select) may be used in potatoes. Metribuzin can cause injury on white, early maturing, smooth skinned varieties, as well as some red varieties. Most growers wait to apply herbicides pre-emergence to potatoes or post-emergence at lay-by or final hilling. Although most herbicide applications are post-plant, EPTC, s-metolachlor, metolachlor, or trifluralin may be applied and incorporated prior to planting (PPI), except in Alaska. Metribuzin can be applied pre-plant incorporated in a tank mixture with EPTC. It can also be applied PPI alone in Idaho, only as a broadcast spray or impregnated on dry bulk fertilizer. In Idaho, Washington, and Oregon, on soils with less than 2% organic matter, trifluralin may be applied in a split application, some at pre-plant and then incorporated, and the rest post-plant. Otherwise, trifluralin can only be applied PPI when tank-mixed with EPTC. Alaska growers experienced damage to Shepody varieties when using EPTC and therefore no longer use it for weed control.

To control emerged **volunteer grain** or a cover crop (e.g., green manures) before planting potatoes, paraquat (Gramoxone Max) or glyphosate (Roundup Ultra Max, others) is occasionally applied pre-plant. This is especially important in fall-bedded fields that are not tilled prior to planting.

Fumigation, although not targeted for weed control, may provide 50% early weed control. The use of green manure crops is sometimes used to control early-emerging weeds.

Nightshades, including volunteer potatoes, can be a serious weed control issue in rotational crops. They can compete with the crop as well as serve as hosts for aphids. Nightshades serve as virus inoculum for potato virus Y (PVY), potato leafroll virus (PLRV), and other viruses, and volunteer potatoes serve as inoculum for late blight *(Phytophthora infestans)*. Volunteer potatoes are very hardy, making their control difficult. An integrated approach using herbicides and tillage is preferred for good control. Many growers control volunteer potato with disking or some type of tillage in the fall after potato harvest to chop up the small tubers that have fallen to the soil surface though the harvest equipment. This type of tillage works well when most of the tuber pieces are left on the soil surface to be killed by freezing temperatures rather than incorporated into the soil where temperatures may not be low enough. Tubers on and below the surface will not be killed unless the temperature falls to 28°F or below. In many soils, this temperature may not be reached below a certain depth, depending on the year and location.

Maleic hydrazide, a growth regulator, is sometimes used in the potato crop late summer to early fall to suppress sprouting of tubers left in the field after potato harvest that might become volunteers in the crop planted the year after potatoes are grown.

Several herbicides that can contribute to volunteer potato control are registered in various rotational crops.

Small Grains:

- bromoxynil + MCPA (Bronate), does not work as well on volunteer potatoes
- carfentrazone-ethyl (Aim)
- dicamba (Clarity or Banvel)
- clopyralid (Curtail, Stinger, or Clopyr Ag)
- fluroxypyr (Starane)
- glyphosate (Roundup Ultra Max, others) – pre-harvest treatment (hard dough stage)
- tribenuron methyl (Express)
- tribenuron methyl + thifensulfuron methyl (Harmony Extra)
- glyphosate (Roundup Ultra Max and others), as a pre-harvest treatment at grain's hard-dough stage.

Corn:

- carfentrazone-ethyl (Aim)
- mesotrione (Callisto)

Sugarbeet:

- clopyralid (Stinger)
- fluroxypyr (Starane)
- glyphosate (RoundupUltra Max, others), as weed wiper application

Cabbage (applies to Alaska only):

- oxyfluorfen (Goal)

Critical Needs for Management of Weeds in PNW Potatoes Pre-plant

Research

- Investigate weed seed banks' contributions in potato cropping systems.
- Determine effect of herbicide carryover to rotational crops, especially new and developmental herbicides.
- Develop herbicides with shorter soil residual to help with rotation challenges.
- Determine tillage and irrigation practices that can enhance herbicide degradation before planting potatoes the year following herbicide use in rotational crops.
- Discover new chemicals that are safe for potatoes grown in coarse-textured (sand, loam), low-organic-matter, and/or high pH soils.

- Cooperate with other researchers evaluating products and practices used in crops other than potatoes for controlling weeds that are a problem in potatoes, such as hairy nightshade, black nightshade, cutleaf nightshade, quackgrass, and field bindweed.
- Investigate volunteer potato control in rotational crops.
- Develop herbicides with new modes of action, especially for control of triazine-resistant weeds (pigweed and common lambsquarters), and ALS-herbicide resistant weeds (common lambsquarters and Russian thistle).
- Explore the use of weed-suppressing cover crops and green manures using an interdisciplinary research approach.
- Examine linkages of cultural practices for other pests and the impact these cultural practices have on weed control.
- Evaluate winter annual weed control and the role of these weeds as hosts for other insect and disease pests.
- Research strategies for controlling weeds in green manures and cover crops.
- Research the use of the fumigant chloropicrin to stimulate yellow nutsedge germination for enhanced control possibilities.
- Research the potential for weed biological controls using weed seed-eating insects.
- Determine effective weed management tactics for drip irrigation in potatoes where no tillage operations are conducted after the drip lines are placed in the potato beds.
- Determine inputs required for an effective green manure crop, including weed control in the green manure crop, irrigation, nutrients/fertilizer required by the green manure crop, and the timing of and equipment used for soil incorporation.
- Determine the effectiveness of green manure crop incorporation with no herbicides applied in potatoes planted after incorporation of the green manure, or with low-levels of herbicides for weed control in potatoes.
- Determine the economic impact of weed control/suppression by green manure crops incorporated into the soil before potato planting.

Regulatory

- Expand herbicide registrations to allow for fall applications of herbicides in order to match changes in cultural practices and/or to allow pre-plant applications not currently labeled.
- Review surface and ground water issues related to the environment (e.g., buffer zones) with the goal of achieving an understandable, applicable global policy.
- Expand herbicide labels to allow application methods not currently allowed (especially chemigation).
- Continue to register new herbicides for volunteer potato control in rotational crops.
- Regulate invasive weed species.
- Work with EPA in addressing FQPA issues to provide realistic and commonsense risk assessment data in order to avoid loss or cancellation of commonly used/needed herbicides.

- Identify minor-use needs and translate needs to IR-4 priority and/or relationships with registrants to influence their priority lists.
- Harmonize herbicide registrations and labels between the United States and Canada.
- Include herbicide mode of action group/classification on the label.
- Work with EPA to investigate the allowance of an herbicide label for use on potatoes by a group of growers, or by growers in a specific region, with "sign-off" by those growers for acceptance of no liability by the herbicide manufacturer/distributor.

Education

- Educate growers and crop advisors on the use of green manure systems for weed management.
- Educate all pesticide applicators about herbicide mode of action and integrated weed management practices (such as record keeping) for herbicide resistant-weed management.
- Provide web-based weed management information.
- Develop extension bulletins and fact sheets for new potato herbicides, new uses for standard potato herbicides, and new weed management practices.
- Educate growers, extension educators, consultants, and retail and herbicide manufacturer representatives on how to identify and report new invasive weed species.
- Educate growers, extension educators, consultants, and retail and herbicide manufacturer representatives on how to identify and report herbicide-resistant weed biotypes/populations.
- Increase technology transfer about new weeds, herbicide resistance, critical weed interface periods, and benefit/risk analysis of herbicide use.
- Develop online weed management recommendations.
- Develop online weed identification website.
- Develop online databases that include search functions for pesticides by pest type.

PLANTING
(FEBRUARY 15 – JUNE 10)

- **Columbia Basin WA, OR—February-April**
- **Treasure Valley OR, ID—March-April**
- **Magic Valley ID—March-May**
- **West of the Cascades (OR and WA)—April-May**
- **Southeastern Idaho—April-May**
- **Eastern Idaho—April-June**
- **Alaska—May**

Growers prepare their fields properly to maximize quality and yield. At planting, soil moisture is 60% to 80% of field capacity in the upper two feet. Some growers make fertilizer applications at planting if pre-plant applications were not used or if only a portion of the fertilizer was applied pre-plant. By placing fertilizer properly, growers avoid damaging seed pieces.

Cultural practices used at planting to aid in pest management include reducing time between cutting seed pieces and planting to minimize seed piece decay; monitoring seed piece size, since small pieces lead to weaker plants that are more susceptible to disease; monitoring soil temperature for proper planting time; and maintaining proper planting depth.

Hilling allows shallower planting of the seed pieces for rapid emergence and at the same time provides the soil depth necessary later in the season for proper tuber development and reduced exposure to sunlight and adverse temperatures. Exposed tubers develop a green color from chlorophyll formation. Glycoalkaloid levels typically are higher in the skin and cortex of green tubers and, along with chlorophyll, cause a bitter taste.

Nematodes

In fields not fumigated in the fall, non-fumigant nematicides can be used at planting or post planting. In fields that were fumigated in the fall, growers sample for nematodes again before planting to determine if a non-fumigant nematicide application is warranted at planting and/or post planting. Nematicides used at planting can include aldicarb (Temik), ethoprop (Mocap), and oxamyl (Vydate).

Aldicarb exhibits systemic and contact nematicidal activity, as well as reducing Verticillium wilt/early die. In addition, aldicarb is highly water-soluble and is able to move up and down in the potato hill with the wetting front, making it effective against mobile nematodes (e.g., stubby-root nematodes). Its systemic activity affects nematodes as they feed on the root system of treated potato plants. Aldicarb can only be applied on sprinkler-irrigated fields. Temik has a pre-harvest interval (PHI) of 150 days, so it can only be used at planting of long-season varieties. Temik granules can be applied with seed pieces in the planting furrow, a method called in-furrow treatment, or in a modified in-furrow placement (6-inch band between planting shoe and closing discs). Temik may also be applied as a 6-inch band in front of the opening shoe but must be covered with 2 to 4 inches of soil. Banded treatment can increase nematode control efficacy without negatively impacting insect control.

Oxamyl (Vydate) is a systemic nematicide that is very effective in controlling all nematodes. However, oxamyl is sensitive to pH, which can create a major constraint in its use. Further, oxamyl has a short half-life, requiring multiple applications during the growing season. Additional benefit can be achieved by using oxamyl in combination with other nematicides such as aldicarb (Temik) or ethoprop (Mocap) at planting. Oxamyl can be applied in-furrow at planting but is also used as a foliar spray later in the growing season. In-furrow application is particularly important to control TRV and root-knot nematodes. Oxamyl is often referred to as a "nematistat," meaning that it prevents damage by root-knot nematodes but does little to reduce populations.

For **root-knot nematodes**, both Columbia and northern, growers treat with ethoprop or aldicarb if sampling determines that population thresholds have been reached. Oxamyl has acceptable efficacy on low populations. Preliminary testing of fosthiazate has been conducted in the PNW on root-knot nematodes, and results show good efficacy.

Growers who have fumigated for **root-lesion nematodes** in the fall sometimes follow up with an application of aldicarb at planting. Soil sampling after fumigation and before planting is considered inexpensive insurance. If nematode populations are still high, non-fumigant nematicides such as aldicarb and oxamyl effectively control root-lesion nematodes. If *P. penetrans* is present, particularly in long-season areas, treatment is necessary.

Aldicarb and oxamyl effectively control **stubby-root nematodes**. Ethoprop is not effective on stubby-root nematodes because it is a contact nematicide rather than a systemic. Aldicarb applied alone in-furrow at planting, modified in-furrow at planting, in front of the opening shoe, or in combination with foliar applications of oxamyl, results in the lowest incidence of corky ringspot disease and the highest total and marketable yields. Banded treatments of Temik can increase nematode control efficacy without negatively impacting insect control. Additional testing is needed to examine efficacy of fosthiazate on stubby-root nematode.

Critical Needs for Management of Nematodes in PNW Potatoes at Planting

Research

- Increase research on oxamyl application rate, method of application, and timing.
- Investigate fosthiazate application rate, method of application, and timing.
- Determine the efficacy of lower rates of nematicides.
- Investigate the use of different nematicide combinations and different rates.
- Research different formulations of oxamyl (e.g., the granular formulation used in Europe).

Regulatory

- Reduce aldicarb pre-harvest interval to 120 days.
- Allow fosthiazate to be registered for pre- and post-plant uses.

- Require nematode-tested, certified seeds (law exists in ID, WA).

Education
- Educate growers on using nematicides at planting.
- Educate growers about the modes of action of nematicides.

Diseases

Resistant varieties offer simple and economical management of diseases if varieties with effective resistance are available. Resistance can mean total immunity to disease (as with the variety Defender, which is actually *resistant* to late blight), but more commonly the use of resistant varieties slows the progress of the disease, making the disease less destructive and control less expensive.

Seed-borne diseases are important at this crop stage. These organisms include fungal, bacterial, and viral pathogens. Key seed-borne diseases include potato leaf roll virus (PLRV), potato virus Y (PVY), potato virus X (PVX), potato virus A (PVA), bacterial ring rot (*Clavibacter michiganensis* subsp. *sependonicus*), late blight, common scab, Rhizoctonia, and silver scurf. Many diseases that survive in the soil are made worse by seed-borne inoculums such as powdery scab, black dot, Rhizoctonia, Fusarium dry rot, and soft rot.

Seed-borne viruses present a unique problem for potato growers because they cannot be directly controlled. Instead, growers control the associated vectors. Potato leaf roll virus, which causes net necrosis, can be managed by using certified seed, providing certified seed for home gardeners, selecting net necrosis-resistant varieties, removing volunteer potatoes where possible, removing peach and apricot trees (which serve as over-wintering hosts for green peach aphids) or spraying trees with dormant oil, and by checking for and destroying aphids in bedding plants at retail stores.

Planting disease-free seed can help to control the other potato viruses as well. Indeed, the most effective control of most seed-borne diseases is the use of certified seed. Specific diseases partially controlled by the use of certified seed include bacterial ring rot, blackleg (*Erwinia carotovora* subsp. *atroseptica*), early die/Verticillium wilt, late blight, powdery scab, and black dot. Using seed with reduced levels of Rhizoctonia helps control this disease.

Seed-piece decay is caused either by the Fusarium dry rot fungi or by the soft rot bacterium. Often soft rot and dry rot decay occur in combination. Fungicide seed piece treatments are used to manage dry rot seed decay and, by eliminating dry rot, can also indirectly control soft rot, since soft rot often invades Fusarium lesions on seed pieces. No available chemical treatments are directly effective against soft rot.

Growers attempt to plant seed when soil temperatures are between 45 and 65°F. Low soil temperatures delay wound healing in the seed, which can lead to seed-piece decay, while high temperatures, especially if soils are excessively moist, can also lead to seed piece decay problems. Growers avoid planting seed that is cooler than the soil. For fields or areas where soft rot seed-piece decay is known to be a problem, either single drop seed (small, whole seed tubers) or cut seed that has been healed or "suberized" is used.

Seed piece treatments that are effective at this crop stage:

- thiophanate-methyl + mancozeb + cymoxanil (Evolve)—protects against Rhizoctonia, Fusarium dry rot, and late blight
- fludioxonil (Maxim)—effective against Fusarium dry rot, Rhizoctonia, and silver scurf
- fludioxonil + mancozeb (Maxim MZ)—effective against Fusarium dry rot, Rhizoctonia, and silver scurf
- flutolanil + mancozeb (Moncoat MZ)—effective against Fusarium dry rot and Rhizoctonia
- thiophanate-methyl + mancozeb (Tops MZ, Tops)—effective against Fusarium dry rot, Rhizoctonia, and silver scurf
- thiophanate-methyl + mancozeb + imidacloprid (Tops MZ Gaucho)—effective against Fusarium dry rot, Rhizoctonia, and silver scurf

Soil-applied treatments that are effective at this crop stage:

- PCNB (Blocker)—effective against Rhizoctonia, provides some suppression of common scab. The Environmental Protection Agency (EPA) proposed to cancel all uses of PCNB. Details on how long it will be available to growers and for which uses are still unclear.
- flutolanil (Moncut)—effective against Rhizoctonia
- phosphites (Phostrol, others)—effective against pink rot
- mefenoxam (Ridomil Gold)—effective against pink rot and Pythium leak
- azoxystrobin (Quadris)—effective against Rhizoctonia and silver scurf
- pyraclostrobin (Headline)—effective against Rhizoctonia
- mefenoxam + thiamethoxam (Platinum Ridomil Gold)—effective against pink rot

While **pink rot** and **Pythium leak** are usually considered to be either late-season or storage disease problems, an in-furrow application of mefenoxam (Ridomil Gold, Ultra Flourish) for management of these two diseases has been shown to be effective. The same fungicides can be effective when applied to the foliage during the growing season when the tubers are approximately a half-inch in diameter. However, resistance to mefenoxam has developed in the pink rot pathogen population in areas in southern Idaho and in the Pythium leak pathogen in the Columbia Basin. How widespread this resistance is and how important the resistant strains are is unknown.

Critical Needs for Management of Diseases in PNW Potatoes at Planting

Research

- Develop improved methods for managing soft rot.
- Develop an accurate assay for Rhizoctonia in the soil and on seed pieces to predict potential disease problems.
- Develop detection methods for late blight in seed, especially at very low levels.

- Investigate biology of silver scurf organism with regard to resistance development.
- Investigate the need for using both a seed-piece treatment and an in-furrow treatment for Rhizoctonia.
- Investigate strobiluron resistance management issues for early blight. Some data show that in-furrow applications as listed above may contribute to this problem.
- Develop alternatives to in-furrow mefenoxam (Ridomil Gold, Ultra Flourish) treatment.
- Develop a control measure (e.g., chemical, genetic, cultural) for black dot in seed.
- Determine the importance of Verticillium and black dot in seed.
- Look at interactions among different crop protection products applied together at planting and how they affect efficacy and crop safety

Regulatory

- Enforce certified seed laws on imported and domestic seed.
- Implement strong phytosanitary requirements to keep out pathogens not yet established here and to reduce the spread of pathogens.
- Implement aggressive surveillance to support phytosanitary requirements.
- Implement National Seed Standard Memorandum of Understanding (MOU) that addresses seed certification across state lines.

Education

- Increase awareness of importance of seed in spreading viruses and bacterial ring rot and the difficulty of detection in seed.

Insects

The major insects of concern at planting are the **green peach aphid** (GPA), **Colorado potato beetle** (CPB), **wireworms**, and **potato tuberworm**. The first two pests only attack the above-ground portions of the potato plants, whereas wireworms feed on tubers, thus reducing quality. The economically important damage caused by potato tuberworm is tuber damage by larval feeding. Damage caused by these pests is detailed in the crop stages in which the damage occurs, but control measures can be implemented for each at planting.

Green peach aphid IPM begins by planting certified seed. Certification does not mean that potatoes are virus-free, but rather that they meet standards for maximum permitted virus levels. Hence virus inoculum is always present within the production region.

GPA, CPB, and wireworms can be managed in part by seed treatments and in-furrow treatments at this crop stage. At-planting insecticide treatments for CPB, however, are used only in areas where CPB are a chronic annual problem. Occasionally, growers wait until defoliation by the beetles reaches the economic threshold before applying insecticides. Potato tuberworm can be partly managed by planting clean, tuberworm-free seed. More specifically, growers do not plant seed from infested regions. Many of the insecticide treatments used at planting (both soil applied and seed treatments) have activity on CPB, GPA, and wireworms.

A list of soil-applied insecticides that may be applied at planting follows.

Aldicarb (Temik) is a soil-applied, systemic insecticide applied to control CPB and GPA. A change in the pre-harvest interval to 150 days now eliminates post-emergence use. Aldicarb applied at planting will provide 65 to 85 days of aphid and CPB control; therefore, foliar application of other insecticides later in the season may be necessary.

Carbofuran (Furadan) is a soil-applied, systemic insecticide applied at planting for early-season control of CPB and GPA and suppression of wireworms. It does not provide reliable GPA control beyond 50 days, thus increasing the likelihood that foliar application of insecticides later in the season will be necessary. Further, the Environmental Protection Agency (EPA) proposed to cancel all uses of carbofuran in an August 30, 2006 Federal Register Notice. Details on how long carbofuran will be available to growers and for which uses are still unclear. Furadan has a Section 24(c) registration for suppression of wireworms, used at planting to 4-inch rosette. Growers try to avoid using carbofuran in two successive years at the same site in order to prevent CPB resistance, which has been observed in other potato-growing regions.

Ethoprop (Mocap) is a soil-applied insecticide used for wireworm control. For best control, ethoprop is broadcast on the soil and incorporated to a depth of 4 to 6 inches. For light infestations, an in-furrow application can be made in a band that is as wide as possible, ideally 10-12 inches wide.

Fipronil (Regent) is an in-furrow insecticide treatment that has proven effective in controlling wireworms and may provide some early season control of CPB. It is not yet registered for potatoes, but its registration is being reviewed by EPA.

Imidacloprid (Admire Pro, others) is applied to control CPB and GPA. Based on trials conducted in Idaho, Oregon, and Washington, imidacloprid and thiamethoxam-based products provide significantly better aphid control than alternatives. Applied at planting, either as a seed treatment (Admire Pro, Gaucho, Gaucho MZ, Top MZ Gaucho) or in-furrow (Admire Pro), these will provide 80 to 100 days of residual control. Imidacloprid-based seed treatments target CPB and flea beetles, and have also proven effective at reducing wireworm damage on seed pieces.

Oxamyl (Vydate) is applied at planting for systemic control of CPB, GPA, leafhopper, and flea beetle.

Phorate (Thimet) is a systemic insecticide applied at planting for early-season control of CPB and GPA, and to suppress wireworms. It has a short residual and does not give season-long control in longer-growing potato production regions. It does not provide reliable GPA control beyond 50 days, increasing the likelihood that foliar application of insecticides later in the season will be necessary. In eastern Idaho, with a shorter growing season, phorate (Thimet) provides good control, and additional pesticide applications may not be necessary.

Thiamethoxam (Platinum, Cruiser) is applied to manage CPB, GPA, potato aphid, flea beetles, and wireworms. Based on trials conducted in Idaho, Oregon, and Washington, imidacloprid and thiamethoxam-based products provide significantly better aphid control than alternatives; applied at planting, either as a seed treatment (Cruiser) or in-furrow (Platinum), these products will provide 80 to 100 days of residual control. Thiamethoxam seed treatments provide protection against injury from green peach aphid, potato aphid, Colorado potato beetles, and flea beetles, and have also proven effective at reducing wireworm damage on the seed piece.

Critical Needs for Management of Insects in PNW Potatoes at Planting

Research

- Investigate efficacy of different chemistries on wireworms.
- Investigate new methods for wireworm detection in the field using site-specific factors.
- Investigate efficient timing for crop protection product applications.
- Determine the mechanisms and genetics of resistance to wireworms in different potato cultivars, especially the advanced breeding selections.
- Develop anti-feeding or repellent-type compounds.

Regulatory

- Work with EPA in addressing FQPA issues to provide realistic and commonsense risk assessment data in order to avoid loss or cancellation of commonly used/needed pesticides.
- Increase regulations and inspections on bedding plants in greenhouses and *Prunus* spp. to eliminate aphid reservoirs.
- Add wireworms to the registration of imidacloprid products (Admire Pro, Gaucho) for potatoes.

Education

- Educate public (homeowners) on efficacious treatments for overwintering populations of green peach aphid on backyard *Prunus* spp.
- Continue development of a regional early warning system for pest infestations to improve scouting efficiency; expand existing scouting programs.

Weeds

Timing of the hilling operation at planting can affect season-long weed management decisions. For example, if the only hilling is done at planting, a grower will not be controlling weeds that have emerged between planting and potato emergence with another hilling operation. Growers must rely on other means of weed control from planting to row closure and beyond, potentially requiring multiple herbicide applications.

PRE-EMERGENCE
(21 TO 35 DAYS AFTER PLANTING)

Diseases

Several cultural practices are employed pre-emergence to aid in disease management. Growers monitor seed-piece condition for the presence of rot and for indications of proper emergence characteristics. Irrigation management is used to avoid physiological stress before emergence, which helps manage soil-borne diseases such as **Rhizoctonia stem and stolon canker, powdery scab, Verticillium wilt, black dot, common scab, seed-piece decay,** and **soft rot/blackleg**. Dragging off, which involves dragging off the top of a hill and then eventually reshaping it, is used to increase soil temperature at the seed depth, which also aids in management of soil-borne diseases. Cull piles are destroyed to reduce inoculum of **viruses** and **late blight**.

Pythium leak is an occasional problem at this crop stage, but is not treated at this stage. Applications of mefenoxam at planting and post-emergence aid in control.

Powdery scab, an emerging disease problem that is not very well understood, can be a problem during the pre-emergence stage. Currently no fungicides are effective or labeled to control it.

Critical Needs for Management of Diseases in PNW Potatoes at Pre-emergence

Research

- Conduct basic research directed at a better understanding of powdery scab and Rhizoctonia.
- Develop more effective management techniques for powdery scab and Rhizoctonia.
- Develop effective treatments to control powdery scab and Rhizoctonia.
- Develop a regional early warning system for potato diseases.

Regulatory

- None listed.

Education

- Educate growers on what is known about powdery scab.

Insects

In Alaska, **wireworms** can occasionally be a problem at this stage. Growers scout fields for wireworm presence. Ethoprop (Mocap) is knifed into the soil as a wireworm control.

Imidacloprid (Admire Pro) can be applied post-plant, pre-emergence to help manage GPA and CPB.

Critical Needs for Management of Insects in PNW Potatoes at Pre-emergence:

Research
- Study the establishment and dynamics of pests.
- Investigate insect-plant interactions leading to pest infestations.

Regulatory
- None listed.

Education
- None listed.

Weeds

Irrigation management and cultivation are employed as part of weed management during the pre-emergence stage. A timely hilling operation—just prior to an herbicide application and just before potato emergence—is common in many parts of the PNW. "Dragging off" (knocking the hills down until almost flat) is sometimes used to hasten emergence and aid in weed control. Some growers use reservoir-tillage (i.e., employment of a Dammer-Diker® implement) prior to potato emergence to enhance irrigation water incorporation and to prevent water run-off on sloped fields.

Herbicide use and incorporation are also common at this crop stage: most potato herbicide applications are made prior to emergence of the potato crop. Variety selection and crop rotation may dictate herbicide choice. Weeds that have not emerged are controlled before the potato crop emerges with dimethenamid-p (Outlook), EPTC (Eptam), flumioxazin (Chateau), metribuzin (Sencor, others), pendimethalin (Prowl H_2O/3.3EC), rimsulfuron (Matrix), s-metolachlor (Dual Magnum/Dual II Magnum), metolachlor (Stalwart), or trifluralin (Treflan HFP); weeds already emerged can be controlled with metribuzin (Sencor), rimsulfuron (Matrix), glyphosate (Roundup Ultra Max and others), paraquat (Gramoxone Max), linuron (Lorox) (AK only), clethodim (Select), or sethoxydim (Poast Plus). Ethalfluralin (Sonalan) may or may not be labeled for use in 2007. All of the herbicide used at pre-emergence are commonly included in 2- and 3-way tank mixtures, and many are applied with chemigation. With the exception of glyphosate, paraquat, clethodim, and sethoxydim, these herbicides will provide residual weed control after application. Depending upon herbicide characteristics, soil structure, and environmental conditions, some can provide control throughout the growing season. Most of these herbicides are labeled for application by air, ground, or overhead chemigation.

Although some herbicides can be mechanically incorporated, most herbicides applied pre-emergence by ground or air (except glyphosate or paraquat) are sprinkler-incorporated to move the herbicide into the weed germination zone in the top 1 to 2 inches of soil. This also "activates" the herbicide, enabling weed uptake, and is less damaging to the potatoes than mechanical incorporation. Rainfall with enough moisture *in a single event* to move the herbicides into the weed seed germination zone can suffice for incorporation. EPTC, trifluralin, and ethafluralin must be incorporated as soon after application as possible to avoid loss by volatilization or photodegradation. Glyphosate, paraquat, clethodim, and sethoxydim are NOT incorporated.

Dammer-Diker® equipment may be employed after herbicide application. When this type of tillage is performed after herbicide application, weed control can be reduced since the herbicide "barrier" is broken and untreated soil can be brought up from below. Some growers in the PNW have placed herbicide spray equipment on the rear of their Dammer-Diker® so that the herbicide is applied after the tillage implement disturbs the soil. In this case, the herbicide needs to be sprinkler-incorporated.

Critical Needs for Management of Weeds in PNW Potatoes at Pre-emergence

Research

- Determine effective weed management tactics for drip irrigation in potatoes where no tillage operations are conducted after the drip lines are placed in the potato beds.
- Develop new pre-emergence herbicides, especially for white-skinned potatoes, since metribuzin cannot be used, and for red-skinned varieties for which little herbicide tolerance testing (other than metribuzin) has been conducted.
- Facilitate herbicide-resistant weed management using the principles of Integrated Weed Management. This includes development of pre-emergence herbicides with modes of action not commonly used in potatoes and potato cropping systems. The most important weeds to target are those that have developed resistance to commonly used sulfonylurea herbicides such as rimsulfuron and populations resistant to Photosystem II Inhibitor herbicides such as metribuzin.
- Investigate sprinkler incorporation to determine amounts needed for pre-emergence herbicides in varying soil moisture conditions and in conditions conducive to moderate to high herbicide mobility.
- Create a region-wide detection and monitoring system for new weed species and herbicide-resistant weed biotypes/populations.
- Evaluate variety response to new herbicides and new variety response to currently labeled and developmental herbicides.
- Provide growers with more weed control tools. Some plant-back intervals on herbicides labeled for use on crops in the potato rotation are extremely restrictive. Little or no research has been conducted in the PNW's semi-arid, irrigated conditions. Obtain and evaluate real-world data on the degradation of herbicides used in other crops grown in rotation with potatoes and the effects on potatoes planted the following season after use. Likewise, obtain and evaluate data on potato herbicide degradation and effects on crops planted the following season after use in potatoes.
- Investigate biological controls, e.g., weed-seed-eating beetles.
- Determine herbicide distribution in the furrow and the potato hill before and after post-application tillage, including reservoir tillage (Dammer-Diker®) or cultivation. Develop recommendations for herbicide application timing and herbicide spray boom placement on tillage equipment in relation to reservoir tillage operations.

- Develop a region-wide survey to determine presence of herbicide-resistant weed populations and levels and types of resistance.

Regulatory

- Regulate invasive weed species.
- Work with EPA in addressing FQPA issues to provide realistic and commonsense risk assessment data in order to avoid loss or cancellation of commonly used/needed herbicides.
- Identify minor use needs and translate needs to IR-4 priority and/or relationship with registrant to influence their priority lists.
- Harmonize herbicide registrations and labels among potato production states and regions.
- Include herbicide mode of action group/classification on the label.
- Work with EPA to investigate the allowance of an herbicide label for use on potatoes by a group of growers, or by growers in a specific region with "sign-off" by those growers for acceptance of no liability by the herbicide manufacturer/distributor.

Education

- Educate growers, extension educators, consultants, and retail and herbicide manufacturer representatives on how to identify and report new invasive weed species.
- Educate growers, extension educators, consultants, and retail and herbicide manufacturer representatives on how to identify and report herbicide-resistant weed biotypes/populations.
- Increase technology transfer about new weeds, herbicide resistance, critical weed interface periods, and benefit/risk analysis of herbicide use.
- Develop online weed management recommendations.
- Develop online weed identification website.
- Develop online databases that include search functions for pesticides by pest type.

EMERGENCE TO HARVEST

Growers perform hilling operations in sprinkler-irrigated fields when plants are emerging. Hilling and reservoir tillage (Dammer-Diker®) operations must be completed before plants become too large so as to minimize severe root pruning. Discs, rolling cultivators, hilling listers, or implements with winged cultivator teeth are used.

Yield and quality of the potato crop are affected by the availability of soil water. Too little water can reduce yields, causing tuber malformations or Verticillium wilt symptoms. Excess or poorly timed irrigation may reduce yields and tuber quality, increase disease problems in the field or in storage, and leach nutrients, insecticides, and herbicides from the root zone.

Soil and petiole analysis are used to determine fertilizer needs. Desired levels of nutrients are maintained by applying fertilizer as a side dressing or through the irrigation system. If nutrient deficiencies occur during tuber growth, the plant shunts nutrients from the stems and leaves to the growing tubers, thereby hastening aging of the vines. As a result, certain diseases such as early blight and Verticillium wilt are aggravated and yields are reduced. On the other hand, excess fertilizer delays the onset of tuber growth in indeterminate cultivars and may reduce yields. It can also increase infestation levels of sap-feeding insect pests and mites. Tuber decay after harvest may also be increased if fertilization was excessive, and processing qualities such as specific gravity (percent solids) may be decreased.

Some growers apply maleic hydrazide (Royal MH-30) during the growing season to suppress sprout formation later on in storage. This product must be applied during active growth in order to be transported to the tubers and effectively suppress sprouting. Typical timing is approximately 11-12 weeks after emergence. Improper timing can result in non-effective sprout suppression, phytotoxicity, reduction in tubers per plant, tuber size reduction, or cracking of the tuber skin. Cultivars differ in response to maleic hydrazide. Maleic hydrazide is also used for volunteer potato control, primarily to prevent the spread of diseases (see *Diseases* in this section).

Nematodes

Columbia root-knot, northern root-knot, root lesion, stubby-root and **potato-rot nematodes** can be present and causing damage at this crop stage.

After potatoes emerge, growers sample roots to determine presence and numbers of root-knot and lesion nematodes. If root-knot or lesion nematodes are detected in the soil or root samples, growers often use foliar applications of oxamyl (Vydate) at this crop stage. There has been an increase in the use of oxamyl to target nematodes in the past few years, leading to a decrease in pre-plant fumigation.

Critical Needs for Management of Nematodes in PNW Potatoes from Emergence to Harvest

Research
- Research appropriate application rate, timing, and method for oxamyl; research how best to combine it with other nematicides.
- Develop slow-release nematicides.
- Study the impact of different combinations of nematicides.
- Determine the number of oxamyl applications for root-knot suppression.

Regulatory
- Register different formulations of oxamyl (e.g., granular formulation used in Europe).

Education
None listed.

Vertebrate Pests

Growers used zinc phosphide under a Section 18 emergency exemption to control **rodents** for several years. EPA issued a tolerance on potatoes in October, 2003 and subsequently approved the registration of a zinc phosphide pellet product called Prozap. USDA-APHIS has developed a zinc-phosphide-impregnated wheat-seed product for use as bait against rodents, but has not yet registered this product.

Critical Needs for Management of Vertebrate Pests in PNW Potatoes

Research
- Working with other commodity groups, research a modeling program to predict rodents.

Regulatory
- Encourage USDA-APHIS to complete registration packet for their formulation of zinc phosphide.

Education
- Educate growers about the management of rodents.

Diseases

Growers control volunteer potatoes in neighboring fields in order to prevent spread of diseases. Maleic hydrazide may be used for volunteer potato control. However, recent research at Washington State University has shown that the smaller tubers, which make up the majority of volunteer potatoes, also have the lowest residues of maleic hydrazide. These low residues are probably not enough to prevent the smaller tubers left in the field from producing volunteer plants the following year, but may be beneficial for the larger tubers remaining.

At the post-emergence stage to harvest, **late blight** caused by *Phytophthora infestans* is the most damaging disease. The disease pathogen attacks stems, leaves, and tubers. If wet or damp weather continues after infection, the entire plant quickly decays. The disease can spread so rapidly that in a few days an apparently healthy field may be severely damaged. Effective systems for forecasting late blight outbreaks have been established and validated for several production regions of North America, including many areas in the PNW. Such systems rely on examining environmental information for periods where the weather is favorable for late blight development. Recommendations for initial fungicide application and subsequent application intervals are based on these environmental conditions. Unfortunately, such forecasting systems do not seem adequate for accurate prediction of the initial outbreak of disease in the arid, western production regions. New research may remedy this situation.

The two types of chemical control used for late blight are protectant and systemic fungicides. Protectants are initially applied according to disease forecasting models just prior to row closure (i.e., before the vines touch across the rows). Subsequent protectant fungicide applications are then made every 7 to 21 days, depending on weather conditions and the occurrence of late blight. Systemic fungicides are tank mixed with a protectant to avoid resistance and improve efficacy. All systemic fungicides that are active against late blight are locally systemic, meaning the fungicides move from one leaf layer to another within a leaf, or move only a short distance in the plant. Local systemics are applied after the disease has been identified through a monitoring program.

Protectant fungicides used for late blight management include chlorothalonil-based products (Bravo, Equus, Echo); ethylenebisdithiocarbamate (EBDC) products (like mancozeb sold as Dithane, Manzate, and Penncozeb; maneb sold as Manex; and metiram sold as Polyram); triphenyltin hydroxide (Super Tin); and fluazinam (Omega, which is also used to control white mold). When triphenyltin hydroxide is used in combination with chlorothalonil or an EBDC, the level of disease control is usually better than using any of the three alone. Copper-based fungicides (Kocide, Nucop) have some efficacy against late blight, but are not as effective as the standard protectants (chlorothalonil and EBDCs). As with triphenyltin hydroxide, copper-based compounds perform better when used in combination with chlorothalonil or an EBDC product. Applications of protectant fungicides need to continue until harvest. Late season applications are particularly important since environmental conditions during this period favor spread of infection, as well as favoring tuber infection.

Locally systemic fungicides used for late blight management include cymoxanil (Curzate), famoxadone + cymoxanil (Tanos), fenamidone (Reason), cyazofamid (Ranman), dimethomorph (Acrobat), zoxamide (Gavel, also contains EBDC), propamocarb hydrochloride (Previcur), azoxystrobin (Quadris), trifloxystrobin (Gem) and pyraclostrobin (Headline).

How fungicides are applied is extremely important for effective control of late blight. Of the three general application methods, air, ground, and chemigation, ground has been shown to apply more material to the canopy than any other method. The most important factors, regardless of method, are to: ensure application without skips; ensure that the timing of the first application is prior to late blight exposure; use the right material; and continue on an application schedule that provides continuous protection of new growth. This also maintains an effective level of residue in the canopy to provide adequate protection. When applying product by chemigation, growers use the least amount of water to limit runoff onto the soil.

The protectant fungicides used for managing late blight, with the exception of fluazinam, are also effective in managing potato **early blight**, caused by *Alternaria solani* and *Alternaria alternata*. Disease caused by *A. alternata* has also been called brown spot. The locally systemic materials labeled for control of late blight are not effective against early blight. The most effective fungicides for managing early blight are the QoI (quinine outside inhibitor) fungicides such as azoxystrobin (Quadris), pyraclostrobin (Headline), trifloxystrobin (Gem), fenamidone (Reason), and famoxadone + cymoxanil (Tanos). Pyrimethanil (Scala) will also provide protection against early blight. Sound agronomic practices such as proper plant nutrition, water management, proper management of other pests, and avoidance of other plant stresses can also greatly reduce early blight severity. Copper-based sprays are not as effective as chlorothalonil- and EBDC-based products on early blight.

Pink rot caused by *Phytophthora erythroseptica* can often be found in the field before harvest. It is characterized by rotted tuber tissues that turn pink after exposure to air for ten to thirty minutes. Tubers infected with the pink rot pathogen later become susceptible to bacteria that cause soft rot decay. Good irrigation practices that maintain proper moisture content (not excessive) will help to minimize this disease. The only fungicides effective in controlling pink rot are the systemic fungicides mefenoxam (Ridomil Gold EC, Platinum Ridomil Gold, Ultra Flourish, Ridomil Gold Bravo, Ridomil Gold Copper, and Ridomil Gold MZ) and phosphorous acid (Phostrol, Fosphite, Crop-phite, Resist 57, and several others). Mefenoxam-based products can be applied at planting with some growers making a second application two weeks later. Mefenoxam and phosphorous acid products are also applied when the largest tubers are approximately a half-inch in diameter, repeating application at 14-day intervals for 2-3 total foliar applications. Mefenoxam used to be very effective against late blight until mefenoxam-resistant strains of the late blight pathogen became predominant in the mid-1990s. Mefenoxam + thiamethoxam (Platinum Ridomil Gold) is a new fungicide used for pink rot that can be applied at planting or at hilling. All foliar-applied mefenoxam products are pre-packaged with a protectant such as chlorothalonil or mancozeb in order to provide foliar protection for late blight and early blight. Additional alternatives to mefenoxam are needed with the occurrence of mefenoxam-resistance in the pink rot pathogen populations in eastern Idaho.

Potato **viruses** important after emergence in the Pacific Northwest include potato leafroll virus (PLRV), tobacco rattle virus (TRV, the cause of corky ringspot), PVX, PVA, and several strains of the PVY-mosaic complex. Simple contact between a healthy and an infected plant can mechanically spread PVX, PVY, and PVA, though insect transmission is most important. PLRV and TRV cannot be spread mechanically but rely on a vector such as aphids for spread. Foliar viruses (PVY, PVX, PVA, PLRV) are managed principally through the use of certified seed potatoes. Purchase of certified seed is the best management tactic for PVY or PVA, since aphids can spread these viruses even when an effective insecticide program is used. In contrast, PLRV management includes using certified seed combined with the use of systemic insecticides, in-season aphid scouting, and late-season aphicide applications when aphids are present. In the case of viruses, the higher amount of virus in the seed when planted increases the risk of current season spread. Management procedures for corky ringspot include use of certified seed and (most importantly) use of nematicides like oxamyl (Vydate) or soil fumigation.

Beet leafhopper-transmitted virescence agent (BLTVA) is another important disease spread by insects during this period, particularly in the Columbia Basin. This disease is caused by a phytoplasma, a very small organism much like a bacteria. The beet leafhopper is the primary vector. Phytoplasmas can cause a wide range of symptoms in potatoes, including leaf curling and purpling, aerial tubers, chlorosis, and early senescence. BLTVA can reduce both yield and quality of potatoes, and apparently can impact most if not all potato cultivars grown in the region. Application of insecticides, primarily in late May and early June, reduces damage substantially, but additional applications of insecticides are necessary to reduce levels of insects throughout most or all of the season. This is discussed further in the *Insects* section, below.

A complex of organisms, including the fungus *Verticillium dahliae*, the nematodes *Pratylenchus penetrans* and *P. neglectus*, and the bacterium *Erwinia carotovora,* causes the disease called potato **early die**. *Verticillium dahliae* is the most important of these organisms. Foliar symptoms resemble a mature senescing potato plant and include uneven chlorosis, yellowing between leaf veins that may turn brown, and vascular discoloration of the stem tissue at and below the soil line. Potato early die is managed culturally by planting certified seed, using a balanced fertility plan, maintaining optimum soil moisture levels, using resistant varieties, and rotating crops (planting potatoes at the most once every three years). Chemical control is not employed at this plant stage, but occurs pre-plant by applying metam sodium (Vapam, Busan, Metam) through sprinkler irrigation systems or by shank-injection.

White mold caused by *Sclerotinia sclerotiorum* is another fungal foliar disease of potatoes. This fungus has a wide host range and is pathogenic on more than 350 different species of plants. Other important hosts are beans, peas, canola, and some of the common weeds associated with potato production like lambsquarters and pigweed. Cultural practices for managing this disease include long crop rotations (especially with non-susceptible hosts like grain), good weed control, and fertility management that reduces excessive vine growth. Proper irrigation is a critical factor in dealing with potential white mold problems. Only three fungicides, fluazinam (Omega), boscalid (Endura), and iprodione (Rovral) have shown efficacy in controlling white mold. PCNB (Blocker) has shown some efficacy when mixed with iprodione. These fungicides are all protectant in nature and should be applied before the disease has become well established in the field. Recent research has shown these new products, when used at initial full bloom, reduce the amount of white mold. Apparently, potato blossoms are extremely susceptible to this disease. They become infected and then fall to the ground or become attached to the lower potato stem, initiating infection. PCNB also has activity on Rhizoctonia. Fluazinam and boscalid are newer and more effective on white mold than iprodione. However, the Environmental Protection Agency (EPA) proposed to cancel all uses of PCNB. Details on how long this chemical will be available to growers and for which uses are still unclear.

Powdery scab, caused by *Spongospora subterranea* subsp. *subterranea,* creates cosmetic defects that can lead to rejection in fresh market potatoes. This pathogen can also be a vector for the potato mop-top virus. This virus has been reported infecting potatoes grown in at least 10 states, though symptoms have only been found in Maine. Currently, no fungicides are labeled for control of powdery scab.

The fungus *Colletotrichum coccodes* causes **black dot**. The disease gets its name from the abundant black sclerotia that form on above- and below-ground portions of the basal stem area. Sclerotia can also form on tubers, stolons (fruiting portion of stem), and roots. Infected plants will be reduced in size and may die early resulting in smaller tuber sizes. At harvest, portions of infected stolons may cling to tubers. Sclerotia on tubers in storage may give the tuber a grayish cast, which can be confused with silver scurf. This disease usually goes undetected. Growers managing their crop for black dot rotate crops, plant certified seed, and use azoxystrobin (Quadris) as a foliar fungicide spray.

Aerial **stem rot**, caused by *Erwinia carotovora* subsp. *atroseptica*, *Erwinia carotovora* subsp. *carotovora,* and *Erwinia chrysanthemi,* is characterized by a soft rot of potato leaves, petioles, and stems. Growers apply copper-based sprays (Kocide, Nucop) as soon as possible after infection is suspected (generally following a severe rain or hail storm) to suppress disease development.

Powdery mildew fungus is almost entirely superficial on the potato plant, but can cause economic damage. Powdery mildew can be managed by applying azoxystrobin (Quadris) or sulfur compounds (Microthiol) before infections are established.

Pythium leak was historically considered primarily a late-season field or storage problem, usually managed with an application of mefenoxam at tuber initiation and again two weeks later. However, this disease can also cause substantial damage during the season, particularly where strains resistant to mefenoxam have been found. Water management is critical in these areas. Damage caused by Pythium leak is detailed in the *Harvest* section.

Common scab is caused by the bacterium *Streptomyces scabies*. Most scab infections occur early in the growing season after tuber initiation. The bacteria invade recently formed pores but do not invade directly through intact skin. Small spots become visible on the tubers, followed by formation of a wound barrier below the surface, hence the name scab. Deep, severe lesions are referred to as pit scab. Scab development does not occur in storage, only during plant growth. Common scab is favored by dry soil, particularly during the early part of the growing season. Soils with a high calcium level and soils rich in non-decomposed organic matter favor the disease. Optimal soil moisture in the top 9 inches of soil suppresses common scab. The most critical time for irrigation management is a period of five weeks after tuber initiation. On fields where common scab is not a severe problem, high moisture alone is sufficient control.

Critical Needs for Management of Diseases in PNW Potatoes from Emergence to Harvest

Research

- Search for alternatives for pink rot and Pythium leak management.
- Improve current disease forecasting models and develop additional ones.
- Improve fungicide deposition on potato stems.
- Investigate early blight to understand more about the disease including how aggressive the different species are and what fungicides are effective against them.
- Develop effective management practices to combat *Erwinia* (stem soft rot).
- Investigate bacteria that cause stem soft rot.
- Determine how interactions of pesticides causing unexpected crop damage impact disease occurrence and severity.
- Learn more about pink eye's basic biology and cause, and develop possible management strategies.
- Develop fungicide formulations for chemigation application.
- Investigate the association between foliar late blight and tuber late blight.
- Determine etiology of bumpy tuber syndrome.

Regulatory

- Facilitate registration of new chemicals with new modes of action to avoid resistance issues.
- Maintain tolerances for fungicides on potatoes.
- Improve inspections and enforce late blight and other disease restrictions on greenhouse, garden tomato transplants, and other garden sources (international).

Education

- Continue to teach resistance-management strategies to maintain longevity of effective pesticides.
- Educate home gardeners, organic growers, and nursery operators on dangers of importing late blight.
- Educate growers on black dot identification.
- Educate growers about white mold control.

Insects

Commercial potato growers generally consider **green peach aphid (GPA)** to be the most serious insect pest of potatoes in the Pacific Northwest. Although this sap-sucking insect sometimes occurs in high enough numbers to directly reduce crop yield, the main economic threat this pest poses is as a vector of potato leafroll virus (PLRV), potato virus Y (PVY), and other viruses. PLRV reduces crop yield but is especially important because it reduces crop quality. Infected plants produce tubers with an internal discoloration defect called net necrosis. Net necrosis is most severe in long-season potato varieties, especially Russet Burbank, and it increases in severity after harvest in storage.

Potato processors and packers tolerate little to no net necrosis symptoms because consumers demand defect-free produce. Hence, the economic threshold that justifies foliar applications of insecticides for GPA is extremely low: one GPA per plant can warrant treatment. Particularly conservative thresholds are utilized in leafroll-susceptible potatoes that will be held in storage before they are marketed, because net necrosis symptoms can continue to worsen after harvest. Low treatment thresholds complicate aphid scouting programs by requiring impractically large sample sizes. In practice, many growers apply foliar insecticides at first detection of aphids.

Even if growers plant certified seed, virus inoculum can be present within the production region. Seed certification simply means that the seed meets standards for maximum permitted virus levels, not that it is virus-free. In theory, growers could destroy host plants on which overwintering aphids survive in order to reduce the number of aphids that subsequently migrate from these plants during the spring and colonize potato fields. In fact, this approach is limited by the extensive host range (875 different plants) of the green peach aphid. Furthermore, extensive area-wide approaches would be required, because winged aphids are carried long distances by the wind. A number of naturally occurring aphid predators, parasitoids, and pathogens are known to occur in Pacific Northwest commercial potato fields, but their impact is minimal because even a small number of aphids causes economic losses. Genetically modified long-season potato varieties have been developed that do not express net necrosis symptoms, but public concern about GM potatoes has prevented the adoption of this technology.

To satisfy quality standards, some growers practice a “no-gap” insecticide application strategy in their net necrosis-susceptible varieties to reduce virus transmission from infected plants to uninfected plants within the field. “No gap” means that the crop is continuously protected with insecticides. Growers apply long-residual systemic insecticides to the soil at planting time and follow these with foliar insecticides that are sequentially applied during the growing season at intervals no longer than their period of residual control. Control measures continue until vines are dead or as close to vine-kill as possible while observing pre-harvest intervals on product labels. Even this intensive GPA control program may fail to prevent disease transmission from virus-bearing aphids migrating into a field from early-season potatoes and winter weed hosts.

Both short-season (early-season) and long-season potatoes receive treatment with systemic insecticides for aphid control. Because long-season potatoes are particularly prone to net necrosis, producers of these varieties treat their crops with maximum label rates of systemic insecticides. Many apply additional foliar materials even when aphid numbers are low in order to maintain the zero gap. In the shorter-season areas of Idaho, such as the eastern Snake River Valley, the growing season is short enough that fewer total aphicide applications are required. In these areas, aphids tend to build up later in the year (August vs. July in the Columbia Basin of Washington and Oregon) and exist in the field for fewer weeks of the growing season (due to late arrival and earlier harvest).

Based on trials conducted in Idaho, Oregon, and Washington, imidacloprid-based products (Admire Pro, Gaucho, Genesis, Provado) and thiamethoxam-based products (Platinum, Actara) provide significant aphid control. Imidacloprid and thiamethoxam applied at planting will provide 80 or more days of residual control. However, thiamethoxam and imidacloprid cannot be used as a foliar spray if any neonicotinoids have been used at planting or have previously been used as a foliar spray. This is due to concerns about resistance. Compared with many foliar-applied insecticides, soil-applied systemics have the advantage of reducing the impact to beneficial predatory and parasitic insects that inhabit the plant canopy.

Foliar aphicides that can be used in early-season potatoes include methamidophos (Monitor), which has a label restriction of a maximum of four applications; pymetrozine (Fulfill), which can only be applied two times during the growing season; endosulfan (Thiodan); imidacloprid (Provado); thiamethoxam (Actara); and cyfluthrin + imidacloprid (Leverage), which cannot be used if the field has been treated with imidacloprid or thiamethoxam during the current year. Leverage has some rotational restrictions, one of the most significant being a one-year plant-back restriction on onions. In years with high numbers of winged GPA, a management program that uses foliar insecticides applied in response to scouting is insufficient to prevent PLRV transmission in late-season Russet Burbank potatoes. Flonicamid (Beleaf) is a newly registered insecticide that has proven highly effective in small plot trials when applied to foliage for control of green peach aphid. Beleaf is highly selective and has little or no activity against other insect pests and beneficial organisms. It has a period of residual control of between 14 and 21 days depending on the rate of application.

Although growers recognize the need to control aphids in all potato fields, many early-season potatoes processed or packed directly from the field receive minimal insecticides as cost-saving measures, because these varieties do not develop net necrosis symptoms as do late-maturing potatoes (e.g., Russet Burbank). These early-season varieties, however, can serve as a reservoir of aphid infestation for other fields. A single, well-timed foliar application prior to development of winged aphids can aid in overall control.

The method of pre-harvest desiccation of early-season potatoes can influence the formation and emigration of winged aphids. This is discussed in the *Vine-Kill* section, below.

Colorado potato beetle is a serious defoliating pest in almost all potato fields in the PNW. CPB has one to three generations per year, depending on the length of the growing season. CPB invade potato fields as adults and lay 300 to 500 eggs on the undersides of leaves over a four-week period. Eggs hatch in four to nine days and larvae feed on terminal growth. Both adults and larvae feed on leaves and stems. Although early-season feeding by adult beetles can be severe enough to eliminate seedling plants, larvae usually are the more damaging during the growing season. If larvae are not controlled, they can cause 70-100% defoliation, death of the plant, and 40% or more yield loss.

A few widespread predators and parasites attack CPB, but not in sufficient numbers to contain CPB populations. However, because the CPB reduces crop yield by feeding on leaves of the plant (rather than directly injuring the crop by feeding on the tuber itself), there is potential for incorporating biological control into CPB pest management systems. Potato plants can tolerate low infestations of leaf-feeding pests without economic loss, so it is not necessary that bioagents reduce CPB infestations to near-zero levels, as is the case for aphids. Pragmatically, the best means of increasing the impact of biological control agents is to use insecticides in ways that minimize harm to these agents. This can be done either by using physiologically selective biorational products that only kill insect pests or by applying conventional insecticides in ecologically selective ways.

Growers routinely use crop cultural methods as part of their CPB management strategy, including crop rotation and elimination of weedy plants that serve as alternative hosts. Physical methods used in eastern U.S. potato production systems (e.g., flamers, vacuums, trench-trapping) are not used in the west, in part due to biological differences between eastern and western beetle populations, but especially because in the west these alternatives are far less cost effective than insecticides for CPB management.

CPB in the PNW are still susceptible to most common insecticides. However, insecticide resistance was discovered in Idaho in the mid-1980s. Widespread and locally diverse esfenvalerate (Asana) and phosmet (Imidan) resistance was detected in all counties in southern and eastern Idaho in 1992. Resistance has the greatest potential to eliminate insecticides as useful tools in CPB management.

In many fields, systemic materials applied at planting for aphid control also control CPB for much of the season. Fields that receive short-residual or no at-planting insecticides are often treated for CPB with foliar applications of relatively inexpensive synthetic pyrethroids (Asana, Ambush, Pounce). Infestations that begin along field edges can sometimes be controlled by spraying only the borders of a field. IPM sampling protocols and economic thresholds have been developed to help growers determine the need for foliar-applied insecticides for CPB, though current thresholds essentially are based on expert opinion rather than research data.

In fields treated for aphids with regular applications of methamidophos, imidacloprid, or thiamethoxam, CPB will also be controlled. Spinosad (Success), abamectin (Agri-Mek), phosmet (Imidan), imidacloprid, thiamethoxam, and carbaryl (Sevin, Sevin XLR Plus) are listed for CPB in the IPM guidelines. Many of the products are much more expensive than the pyrethroids, so many growers still opt for the cheaper, more broad-spectrum materials. This choice can lead to secondary outbreaks of mites and/or aphids by interfering with natural enemies of these pests. Metaflumizone (Alverde) is a new foliar CPB product, registration of which on potatoes is anticipated to occur sometime in 2007.

Currently, there are no post-planting chemicals registered for control of **wireworms**, nor are there any cultural controls growers can use at this crop stage to combat wireworms.

Spider mites can be a serious potato pest, especially within the Columbia Basin of Washington and Oregon and to a lesser extent the Treasure Valley of Oregon and Idaho. Mites become a problem late in the season. Their numbers can increase extremely rapidly, defoliating a healthy field in seven to ten days if uncontrolled. What causes mite outbreaks is uncertain, but entomologists, growers, crop advisors, and others cite these contributing factors: 1) application of non-selective pesticides, such as pyrethroids and certain carbamates and organophosphates, which negatively impact mite predators and allow spider mites to resurge, 2) proximity to certain crops such as corn, alfalfa, and mint, which tend to harbor mites that subsequently move to potatoes when the former crops mature and dry, 3) proximity to dusty roads, and 4) hot, dry weather.

The only three miticides registered on potatoes are abamectin (Agri-Mek), propargite (Comite, Omite), and spiromesifen (Oberon). Spiromesefen and propargite are by far the most commonly used materials partly because they can be applied by air. Abamectin requires application with 20 gallons of water/acre, which is not feasible by air. Additionally, abamectin cannot be applied by chemigation, and most growers are reluctant to apply miticides by ground. None of the products will provide full control or serve as a rescue treatment once mite populations reach outbreak levels. Miticides need to be applied before populations reach two mites per compound leaf. There has been an increase in the use of pyrethroids in areas where potato tuberworm infestation is heavy. This has led to an increased problem with mites.

At least two species of **flea beetles** infest potatoes in the PNW, mainly in western Oregon and the Skagit Valley of Washington. These beetles overwinter in the areas surrounding fields. Adults feed on the foliage, causing a shot-hole type of damage. The larvae feed in the soil on roots and tubers. In severe situations, the yields from entire fields can be rendered unmarketable. Little is known about the best control methods for these beetles. Most growers use at-plant applications of systemic insecticides such as imidacloprid, followed by foliar applications of methamidophos.

A diverse, multi-species complex of lepidopterous caterpillars such as **loopers, armyworms,** and **cutworms** are known collectively as “worms.” Little IPM technology is available for management of worms in PNW potatoes. For example, there are no established economic thresholds for worms, no research-based scouting procedures, and no predictive forecasting models to help growers use insecticides in the best way possible. Worm rates of development and feeding patterns are different from CPB. The most common materials used for worm control are the broad-spectrum pyrethroids. These products are chosen over alternatives such as spinosad (Success) because of price. Cyfluthrin + imidacloprid (Leverage) insecticide is effective in controlling worms but has a moderate effect on beneficial insects. Leverage cannot be used if the field has been treated with imidacloprid or thiamethoxam during the current year. Metaflumizone (Alverde), the new foliar product mentioned for CPB, above, should it receive the registration anticipated in 2007, will also be registered for worm control.

The occurrence of worms in potatoes seems to have increased in recent years. A leading theory is that increasingly widespread use of relatively selective neonicotinoid insecticides applied at planting and to the foliage has replaced the broader-spectrum organophosphate and carbamate insecticides that have historically provided control of these pests.

Lygus bugs are small insects with piercing-sucking mouthparts. They cause minor damage of unknown economic significance. Infestations are localized. Damage commonly consists of flagging of leaflets, leaves, or small stems. Chemical treatment is rarely needed for lygus bugs. Application of pyrethroid insecticides to control this pest can make aphid management more difficult and can lead to outbreaks of spider mites. Many foliar insecticides that are applied for aphids and/or CPB also control lygus, including: cyfluthrin + imidacloprid (Leverage), which cannot be used if the field has been treated with imidacloprid or thiamethoxam during the current year; methamidophos (Monitor), which has a label restriction of a maximum of four applications; and endosulfan (Thiodan).

A wide variety of **leafhoppers** can be found in potato fields. The most important leafhopper for potato producers in the PNW is the **beet leafhopper** (*Circulifer tenellus*). This leafhopper varies in color but is always one of the smaller species and lacks prominent spots or other dorsal markings. Beet leafhoppers live and reproduce mostly in weeds on non-irrigated ground. The reason this leafhopper is important is that it transmits BLTVA (beet leafhopper-transmitted virescence agent) phytoplasma, which is discussed under *Diseases* in this section. Some level of BLTVA is transmitted to potatoes every year, but the virus is extremely severe in years when beet leafhopper numbers are highest.

The beet leafhopper's favorite food plants include wild mustards, kochia, and Russian thistle. Controlling these favored hosts is probably the most important cultural management option. Indications are that beet leafhoppers within several hundred feet of a potato field may be most important in BLTVA transmission. Therefore, controlling beet leafhopper's favorite weed hosts nearby each potato field may reduce BLTVA incidence.

Most BLTVA infection occurs early in the season, during May and June (although some evidence suggests damaging infections in July); therefore, the most important time to control beet leafhoppers is early in the season—the first two months after potato emergence. Frequent applications may be necessary, since the beet leafhopper vector is only a transient visitor to potato fields. One spray may kill the leafhoppers in the field at the time and new invaders for a residual period, but more leafhoppers invade from surrounding areas throughout the season. Applications of pyrethroids for control of this and other pests make aphid management more difficult and can lead to outbreaks of spider mites. Many foliar insecticides that are applied for GPA and/or CPB also control this pest, including: cyfluthrin + imidacloprid (Leverage), which cannot be used if the field has been treated with imidacloprid or thiamethoxam during the current year, methamidophos, which has a label restriction of a maximum of four applications, imidacloprid, thiamethoxam, and endosulfan.

Most leafhopper species do not reproduce in potato fields. One exception is a small, pale green, torpedo-shaped species of the genus *Empoasca*, but these are rarely found in significant numbers in the PNW.

Stink bugs (Pentatomidae) that damage potatoes are usually large (⅜ inch), green, shield-shape bugs. They feed by sucking plant sap. Stink bug damage usually manifests as flagging of leaflets, leaves, or stems. Stink bug feeding at the base of a leaf seems to cause the entire leaf to wilt. Stink bugs are pests of potatoes in isolated pockets in the PNW. Endosulfan, also registered for GPA and CPB, is registered for stink bug management.

Western flower thrips (*Frankliniella occidentalis*) are thought to be serious pests in some parts of the Columbia Basin, where they are treated with methamidophos and other broad-spectrum insecticides. They are not known to transmit viruses to potatoes in the PNW.

Grasshoppers are rarely a problem in the PNW except in Alaska. In Alaska, these insects can reach extremely large numbers area-wide, and must be controlled in potatoes. Growers use materials such as carbaryl (Sevin) and malathion (Cythion).

Potato tuberworm (PTW), *Phthorimaea operculella* (Zeller), is a relatively new pest of concern in the Pacific Northwest. It has been detected throughout most of the Columbia Basin region of Washington and Oregon. In southern Idaho, a few moths have been collected, but no larvae or tuber damage is evident so far. This is an important pest, because processors have a zero tolerance policy. They will reject all potatoes in a shipment if PTW is detected.

The most economically important damage occurs through larval (worm) feeding on the tuber. This feeding can occur in the field and in storage facilities. Larvae excavate tunnels throughout the tuber. Visual spotting of potatoes infested with larvae is difficult because the insect's tunnels at early stages of infestation are very small and very difficult to see. It is necessary to cut suspicious tubers to carefully check for larvae, pupae, and signs of tuberworm damage. Adults (dull-colored moths, approximately 0.4 inches long with a 0.5-inch wingspan) are also hard to see because they are quick fliers and are active at dusk. Early detection of adults with pheromone traps can help growers avoid storing damaged tubers. If tuberworms are suspected to be in potato fields, based upon area-wide trapping information, a single pheromone trap is placed near the edge of the field at crop emergence and is checked weekly. Traps are monitored until the field has been harvested. Currently there is no treatment threshold established for the PNW region.

Tuberworms move between crops and forage up to 0.15 miles to infest tubers or plants. Long-distance movement of tuberworms is probably due to movement of infested tubers. Growers must carefully guard against storing or transporting potato tuberworm-infected tubers.

Best Management Practices (BMPs) for tuberworm management include planting seed from uninfested fields, choosing potato fields as distant from previous potato plantings as possible, eliminating cull piles, cleaning equipment and trucks after handling potatoes in areas known to have tuberworm, and planting and hilling the potatoes so as to minimize shallow set of potatoes, since tuberworms are attracted to exposed potato tubers.

Eliminating damaged tubers and treating the remainder with insecticide is critical. Several products registered for tuberworm control in potatoes have shown efficacy against the pest in limited research trials in Oregon and Washington. These include novaluron (Rimon), methamidophos (Monitor), cyfluthrin (Baythroid XL, Renounce), cyfluthrin + imidacloprid (Leverage), methomyl (Lannate), esfenvalerate (Asana), phosmet (Imidan), and carbofuran (Furadan). Researchers in the PNW are looking at several insecticides currently registered for other potato pests to determine if they have any efficacy on PTW. Once those efficacies have been determined, adding PTW to those labels will need to be pursued. Indoxacarb (Avaunt) is effective on PTW when used at labeled rates; it is being used under 2(ee) provisions of FIFRA. Additionally, metaflumizone (Alverde) is a new foliar product; registration on potatoes for pests including PTW is expected in 2007. To date, growers in Idaho have not needed to apply insecticides for PTW control. In the Columbia Basin of Oregon and Washington management of potato tuberworm usually requires multiple applications of insecticides. Due to the propensity of this insect to develop resistance to insecticides, rotation of products with different modes of action is encouraged. Use of products from three different modes of actions is optimal during the course of a single growing season.

Known factors that predispose a field to damage by PTW include:

- Dry soil**.** Conversely, wet soil may prevent tuber damage.
- Dead vines. Tuberworm larvae live in the leaves and stems of potato plants during the growing season, and evidence suggests that they prefer green foliage over tubers. So, almost all tuber damage occurs after vines begin to die or following chemical defoliation. Dry soil during this time makes tubers especially vulnerable.
- Exposed/shallow tubers. Research around the world has shown that tubers infested by tuberworm larvae are almost always within 2 inches of the soil surface. Tubers deeper than 2 inches are rarely infested.
- Large moth populations**.** Left unchecked, tuberworm populations can become overwhelming.

Management of insecticide resistance is an important issue in potatoes. According to the *2006 Integrated Pest Management Program for Insects and Mites in Oregon and Washington Potatoes:*

The two most significant insect pests of potatoes in the world, Colorado potato beetle and green peach aphid, have developed resistance to many insecticides used for their control. While the Pacific Northwest has largely escaped this problem, the development of insecticide resistance in these pests is still an issue for which the potato industry needs to be prepared. Once resistance to an insecticide is established in a population the utility of the product is largely lost. Avoidance of resistance or resistance management is the best means to preserve the effectiveness of potato insecticides. PNW potato growers will have access to four planting time products—imidacloprid (Admire Pro, Gaucho) and thiamethoxam (Platinum and Cruiser)—and four foliar products—acetamiprid (Assail), imidacloprid (Provado), cyfluthrin + imidacloprid (Leverage), and thiamethoxam (Actara)—that belong to the same class of chemistry, neonicotinoids. Due to certain characteristics of this pesticide class and the propensity of CPB and GPA to develop resistance, the potential exists for development of resistance to the entire class if the products are not used carefully. CPB populations in locations in the Midwest and on the East Coast have already developed elevated levels of tolerance to neonicotinoid insecticides in potatoes, potentially jeopardizing the use of this class of insecticides. It is critical that this situation be avoided in the Pacific Northwest.

Growers knowledgeable about resistance development will not use Provado, Leverage, or Actara in a field in which Admire Pro or Platinum has been applied in-furrow or as a side dress in the same season or where Gaucho or Cruiser seed treatments were used in the same season. This avoids repeat exposure among the insect population to the same mode of action and helps avoid the development of resistance to these valuable products.

Growers may choose to selectively treat parts of a farm or field with neonicotinoids as another resistance management tactic, forgoing treatment of one circle out of five, for example, or skipping one type of potato that is less susceptible to damage.

Critical Needs for Management of Insects in PNW Potatoes from Emergence to Harvest

Research

- Develop effective late-season GPA control.
- Investigate beneficial insects in potato cropping systems, including aphid parasitoids.
- Create a cost-effective GPA detection system that would detect first occurrence of the aphids.
- Increase regional resistance monitoring for CPB and GPA.
- Investigate secondary pest infestations occurring after broad-spectrum insecticide applications.
- Investigate insecticide efficacy on a commercial field scale.
- Develop region-wide monitoring system of GPA, including a website, a hotline, and other communication methodologies.
- Study multiple pest interactions, e.g., vegetation management for pest species and source of natural enemies (insectary crops).
- Study mite-resistant clones.
- Determine vector-efficiency of different aphids for virus transmission.
- Develop practical cultural methods that growers can use to enhance impact of solid canopy-dwelling predatory and parasitic insects.
- Develop management strategies for non-colonizing aphids (PVY).
- Study different cultural practices to control tuberworm, including irrigation techniques.
- Conduct pesticide timing trials for tuberworm.
- Conduct pesticide screening trials for tuberworm.
- Conduct irrigation and desiccant trials for tuberworm control.
- Research population genetics for new and emerging pests.
- Research biological control methods for tuberworm (viruses, bacteria, and nematodes).
- Breed for resistance for tuberworm.

Regulatory

- Work with EPA in addressing FQPA issues to provide realistic and commonsense risk assessment data in order to avoid loss or cancellation of commonly used/needed pesticides.
- Standardize labeling regarding pesticide usage and residues and tolerances.
- Encourage NRCS cost share for IPM tactics.

- Provide pheromone traps for tuberworm for areas that do not yet have it.

Education

- Educate growers to use NRCS cost share.
- Educate growers about resistance management, including the resources that Insecticide Resistance Action Committee (IRAC) provides.
- Educate growers about tuberworm identification, detection, and management.
- Encourage the use of IPM programs.
- Educate growers about beneficial insects, including how to promote them and how chemicals affect them.

Weeds

Control of weeds escaped from PPI or pre-emergence herbicide applications or weed control by a planned post-emergence control program is carried out at this time with awareness of labeled post-harvest intervals (PHI).

Some herbicides are sprayed behind the cultivator and incorporated during subsequent hilling and/or cultivation, or by sprinkler incorporation. Growers use cultivation and hilling to control emerged weeds, and they use hilling to minimize tuber greening. If potatoes are hilled, it is important that this operation be performed just as plants are emerging, with the exception of when the herbicide flumioxazin (Chateau) is used, since it requires at least two inches of settled soil covering any vegetative portion of the sprouting potato. Research has shown that covering emerged Russet Burbank potato plants in the rosette stage decreases both total and U.S. No. 1 yields. If performed correctly, cultivation with no weather delay is an effective weed control measure. However, due to the nature of weed growth and weather patterns, chemical measures are almost always a necessity. It has been shown that two cultivations reduced total potato yield by 12 to 20 percent compared to using herbicides to control weeds. The combination of timely herbicide applications and cultivation is essential in the production of potatoes. Cultivation is cost-effective at low weed densities but not when high weed densities exist. Cultivation timing may be critical and needs to be matched to weed stage, which is not always possible. Cultivation timing is more critical with Shepody and smooth-skin varieties.

Some growers use reservoir-tillage (Dammer-Diker®) after crop emergence to enhance irrigation water incorporation and to prevent water run-off on sloped fields. The implement can be set up to control emerged weeds as well. When this type of tillage is performed after herbicide application, weed control can be reduced, since the herbicide “barrier” is broken and untreated soil can be brought up from below. Some growers in the PNW have placed herbicide spray equipment on the rear of their Dammer-Diker® so that the herbicide is applied after the tillage implement disturbs the soil. In this case, the herbicide needs to be sprinkler-incorporated.

Herbicides used for control of most **broadleaf** and some **grassy weeds** after the potato crop has emerged but before weed emergence include EPTC (Eptam), metribuzin (Sencor and others), pendimethalin (Prowl H_2O/3.3EC), rimsulfuron (Matrix), s-metolachlor (Dual Magnum, Dual II Magnum), metolachlor (Stalwart), and trifluralin (Treflan HFP).

Rimsulfuron (Matrix), metribuzin (Sencor), clethodim (Select), or sethoxydim (Poast Plus) will control emerged weeds. Use of s-metolachlor post-emergence on potatoes is limited because of a history of unacceptable crop injury. S-metolachlor is used for **yellow nutsedge** control with some crop damage expected. These herbicides, except clethodim and sethoxydim, will provide residual weed control after application, and depending upon herbicide characteristics, soil structure, and environmental conditions, can provide control throughout the growing season. Sethoxydim and clethodim may be used for control of already emerged grassy weeds after the potato crop has emerged, but these herbicides do not have residual activity. All of these herbicides are commonly included in 2- and 3-way tank mixtures, and many are applied with chemigation. Trifluralin can be applied after potatoes have fully emerged. It must be incorporated without completely covering emerged potato plants with treated soil. EPTC also must be incorporated after application. All herbicides except metribuzin, sethoxydim, rimsulfuron, and clethodim must be applied before potatoes reach 4-6 inches in height. Only rimsulfuron, metribuzin, sethoxydim, and clethodim have activity on weeds already emerged at application time.

Critical Needs for Management of Weeds in PNW Potatoes from Emergence to Harvest

Research

- Determine effective weed management tactics for drip irrigation in potatoes where no tillage operations are conducted after the drip lines are placed in the potato beds.
- Develop herbicides especially for post crop-emergence with efficacy on emerged weeds.
- Investigate critical weed interference period (the time when weeds absolutely must be controlled to prevent yield loss).
- Investigate weed/pest interactions as reservoirs for disease and hosts for insects and nematodes, and investigate sources of natural enemies for pest species and soil-borne fungi.
- Investigate herbicide resistance management in a cropping systems approach.
- Develop GM potatoes for herbicide tolerance.
- Conduct a weed survey to determine weed species present in potato production areas and the presence of herbicide resistant biotypes/populations.
- Continue research on the relationship between hairy nightshade and green peach aphid, potato leaf roll, and tobacco rattle virus.
- Investigate chemigation of herbicides for application time extension and to determine potato crop safety.
- Investigate enhanced degradation of EPTC (Eptam).
- Determine herbicide distribution in the furrow and the potato hill before and after post-application tillage (i.e., Dammer-Diker® reservoir tillage or cultivation). Develop recommendations for herbicide application timing and herbicide spray boom placement on tillage equipment in relation to reservoir tillage operations.

Regulatory

- Regulate invasive weed species.
- Work with EPA in addressing FQPA issues to provide realistic and commonsense risk assessment data in order to avoid loss or cancellation of commonly used/needed herbicides.
- Identify minor use needs, and translate needs to IR-4 priority and/or relationship with registrant to influence their priority lists.
- Harmonize herbicide registrations and labels.
- Include herbicide mode of action group/classification on the label.
- Work with EPA to investigate the allowance of an herbicide label for use on potatoes by a group of growers, or growers in a specific region, with “sign-off” by those growers for acceptance of no liability by the herbicide manufacturer/distributor.

Education

- Educate growers, extension educators, consultants, and retail and herbicide manufacturer representatives on how to identify and report new invasive weed species.
- Educate growers, extension educators, consultants, and retail and herbicide manufacturer representatives on how to identify and report herbicide resistant weed biotypes/populations.
- Increase technology transfer about new weeds, herbicide resistance, critical weed interface periods, and benefit/risk analysis of herbicide use.
- Develop online weed management recommendations.
- Develop online weed identification website.
- Develop online databases that include search functions for pesticides by pest type.
- Educate growers about the timing of maleic hydrazide treatment according to potato variety.

VINE-KILL

Killing potato vines before harvest is a common practice in many areas of the Pacific Northwest. Killing vines two to three weeks before harvest allows the stolons to loosen from the tubers and hastens tuber maturity and skin set. It generally takes 14 to 21 days for tuber skins to mature once the skin set process has started. A fully mature skin provides excellent disease and bruise protection. The mature skin is also crucial for providing a quality crop during harvesting and storage. Since 60 to 80% percent of potatoes are stored (either on-farm, by processors, or by fresh-pack shippers), minimizing storage loss is very important economically. Mature tubers are more resistant to skinning, are more resistant to shatter bruise during harvest, experience less decay, and lose less water during storage. However, with some varieties, it is recommended that the time from vine kill to harvest be minimized in order to maximize processing quality (e.g., Ranger Russet). These varieties tend to bruise less and do not require as much time for proper skin set.

In areas of the Pacific Northwest where the growing season is particularly short and the ideal harvest window is minimal, vine killing is accomplished by using chemical desiccants or mechanical choppers to hasten tuber maturity so harvest can be completed before freezing temperatures damage tubers in the soil. Although most growers use vine-kill products for reasons other than weed control, some may target late-season weeds with this operation as well, especially **hairy nightshade**, which can germinate, flower, and produce viable seed throughout the growing season. This weed also can form a mat which can interfere with the harvest equipment. It is possible for nightshade weeds to re-grow after vine kill and cause problems at harvest.

Mechanical vine-killing techniques may consist of rolling the vines with weighted tires to crush the vines and open the crop canopy or chopping the vines with a flail-type mower. A combination of vine-kill methods may be used. For example, some growers may chop the vines while pulling a roller behind the chopper to seal the ground and then follow with a vine-killing chemical application two to three days later. Chemical desiccants used include glufosinate-ammonium (Rely), diquat (Reglone), paraquat (Gramoxone Max, not used on potatoes to be stored), carfentrazone-ethyl (Aim), endothal (Des-i-cate II), pyraflufen-ethyl (ET), and sulfuric acid. Chemical desiccation is preferable to dehydration by withholding irrigation, because chemicals desiccants act more rapidly, decreasing the likelihood that aphids will develop winged adults that move to other fields at the end of the season. In contrast, desiccation of potatoes by withholding irrigation slowly dehydrates foliage and can trigger wing formation in aphids and stimulus for flight. Desiccation of potatoes by withholding irrigation should only be used as a last resort. If water management is used to desiccate the crop, it is critical that an effective aphicide such as pymetrozine (Fulfill) or methamidophos (Monitor) be used.

Late blight is still a concern for growers at this crop stage. No research-based treatments are currently in use. Preliminary research in Washington State indicates that EBDC fungicides (Mancozeb) and cyazofamid (Ranman), applied to the soil earlier in the season, may be effective in reducing infection of tubers with the late blight fungus. Theoretically, the protection provided by these products could last until vine-kill.

The time between vine-kill and harvest is critical in terms of **tuberworm** management. Once green foliage is no longer available, tuberworms tend to go in search of exposed tubers. Several trials being conducted at the Hermiston Agricultural Research and Extension Center are focusing on the use of cultural and chemical practices at vine-kill and during harvest.

Critical Pest Management Needs at Vine-Kill in PNW Potatoes

Research

- Investigate vine-kill products' impacts on late-season weed control and weed-seed kill.
- Investigate harvesting and storage of non-vine-killed potatoes.
- Determine effect of vine-kill products on skin set and stem-end discoloration, processing quality, storability, and bruise susceptibility.
- Develop management strategies for control of late blight under slow vine-kill conditions.
- Investigate transmission of late blight under green vines. Determine risk potential of tuber late blight and early blight.
- Investigate management of tuberworm problems at this crop stage.
- Compare rapid vs. slow vine-kill materials and no-vine-kill for effect on bulking and quality of developmental, newly released, and released potato varieties.
- Investigate the effect of vine-kill on tuberworm populations.
- Investigate the effect of vine-kill on hairy nightshade control, including viability of seed from the plant subjected to the vine-kill method.

Regulatory

- Work with EPA in addressing FQPA issues to provide realistic and commonsense risk assessment data in order to avoid loss or cancellation of commonly used/needed desiccants.

Education

- Technology transfer of vine-kill management and consequences
- Continue to educate growers about late blight and tuberworm management at this stage.

HARVEST

Weeds still in the field at harvest time, especially **hairy nightshade, pigweeds,** and **grass weeds** interfere with harvest and cause harvest losses.

Potato tuberworm can be a problem between vine-kill and harvest, as this pest tends to feed on exposed tubers after losing its preferred green plant material. Traps located in the field are monitored until harvest to aid in tuberworm detection.

By far, the primary pest management challenges at harvest are minimizing the amount of damage occurring to potatoes during harvest operations and removing diseased tubers from the lots being placed into storage. **Late blight, Fusarium dry rot, pink rot,** and **Pythium leak** are important diseases that can cause storage rot problems.

Dry rot and leak pathogens require a wound to infect the tubers. Minimizing shatter bruise (broken skin or periderm of the tuber) helps reduce the amount of infection from diseases such as these. Compounding the difficulty of managing shatter bruise is the fact that another bruise type, blackspot bruise (cells just beneath the tuber skin turn black although the skin is not broken), also results in loss of crop quality but is managed differently.

Tuber hydration level (whether a tuber is hydrated and crisp/turgid or dehydrated and limp/flaccid) influences the amount of bruising. Dehydrated tubers are more prone to blackspot bruise, while hydrated tubers tend to exhibit more shatter bruise. There is a point between hydrated and dehydrated that results in the least amount of total tuber bruising. Tuber hydration is influenced by irrigation practices just prior to harvesting. The timing of an irrigation to properly hydrate tubers depends on the desired tuber hydration level, potato variety, and soil type.

Potato pulp temperature at harvest also influences bruising. Ideally, potatoes are harvested with a pulp temperature of 50 to 60˚F. Generally, cold tuber pulp temperatures increase both blackspot and shatter bruise. Cold, hydrated tubers tend to shatter bruise more readily, whereas warm, dehydrated tubers blackspot bruise more easily. Tubers with warm pulp temperatures may not bruise as readily, but warm tubers are at risk of rot problems in storage.

Generally speaking, growers strive to have the proper soil moisture, tuber hydration, tuber temperature, and skin set to minimize bruising, but this varies among potato types. Potato varieties have different responses to bruising management techniques as well as varying degrees of susceptibility to both shatter and blackspot bruising. Besides minimizing bruising, growers also try to minimize the amount of tuber skinning during harvest. Skinning is when the skin is scuffed from the tuber flesh.

Pythium leak is caused by *Pythium* spp., usually *P. debaryanum* or *P. ultimum*. It is characterized by a rot that starts from an infection site on the surface of the tuber and generally rots out the entire central portion of the tuber while leaving the portion of the tuber from the vascular ring out to the skin of the tuber intact. The rotted tissues are brown to black; the texture is soft and watery. Diseased tubers can easily be invaded by soft rot bacteria. Leak invades and destroys tubers rapidly and is usually only a problem in the first several weeks of storage or when shipping out of the field. Leak invades wounds made at harvest under warm tuber pulp temperatures; it is important to avoid wounding during harvest and to avoid harvesting when pulp temperatures are above 65°F. If significant infection is found in storage, high volumes of air and a rapid cool down are used. As with pink rot, treatment with mefenoxam at planting or during the production season is helpful in reducing the amount of disease. Tubers are allowed to remain in the soil for two to three weeks after vine-kill, resulting in more mature skins and less skinning damage. However, the longer tubers are allowed to stay in the soil, the greater the chances of higher levels of **silver scurf** infection.

Critical Pest Management Needs at Harvest for PNW Potatoes

Research

- Investigate management of harvester leavings to prevent problems with subsequent crops.
- Investigate cultivar differences and vine-killing in bruise management.
- Investigate the effects irrigation management on cultivars and bruise.
- Continue to evaluate efficacy of at-harvest, pre-storage chemicals for diseases.
- Document yield loss associated with harvest interference from weeds.
- Investigate the effect of tuber pulp temperatures on disease development.

Regulatory

- Support registration of new disease control products.

Education

- Educate growers about harvest management techniques for control of subsequent volunteer potatoes.

POST-HARVEST

Two major components of managing potato quality in storage are sprout inhibition and disease suppression. If proper sprout control is not maintained, significant detrimental impacts on tuber quality and storability will result. Sprouting causes weight loss and impedes airflow through the potato pile. When airflow is impeded, temperatures rise and the risk of disease increases. Sprouting also converts starch to sugars, which is undesirable in the processing sector. (Higher sugar content leads to darker coloration in fried product.) The visibility of sprouts on fresh pack potatoes is not acceptable to consumers.

After harvest, potatoes are loaded into potato storage areas that can range in holding capacity from 30,000 cwt (3,000,000 pounds) to 250,000 cwt (25,000,000 pounds). Potatoes are piled into the storage in bulk to heights of 12-20 feet. The storage has either soil or concrete floors (with built-in duct systems) and well-insulated walls and ceilings. Stored potatoes require proper airflow, temperature control, and high relative humidity (≥ 90% relative humidity). Air is distributed to the bulk pile of potatoes via a plenum and ducts or tunnels underneath the pile of potatoes. Most modern storages have been designed to supply air at a rate of 10-25 cubic feet per minute/ton of stored potatoes. Temperature within the storage is controlled using airflow. Fresh air is brought into the storage, mixed, and distributed throughout the storage. Potatoes are typically cured for two to three weeks at 50-55°F in order for proper wound healing to occur. Final holding temperatures will be dependent upon cultivar and final use of the potatoes. Typically, seed potatoes are stored at 38°F, fresh potatoes at 40-45°F, and processing potatoes at 45-50°F.

The primary method to control sprouting in storage is use of chlorpropham (CIPC). CIPC inhibits sprout development by interfering with cell division. Since CIPC interferes with wound healing, it must be applied after the wound-healing period (two to three weeks after harvest) but before dormancy break or initiation of sprout growth. Commercial applicators apply CIPC as an aerosol formulation to bulk potatoes in storage. CIPC as a liquid concentrate or a solid product liquefied by heating is pumped into the aerosol-generator. These liquid CIPC formulations are heated into an aerosol that can be delivered into the potato pile by the circulating air system in the storage facility. The rate may vary depending on the variety, storage temperature, and the length of intended storage. Applications of CIPC as an emulsifiable concentrate can be made directly to washed potatoes prior to packaging and shipping to the fresh market. Maleic hydrazide (MH-30) is sometimes applied to potato foliage during the growing season for sprout control in storage. Substituted naphthalenes, 1,4-dimethylnaphthalene (1,4Sight) or diisopropylnaphthalene (Amplify), are sometimes applied as a sprout suppressant in storage, although they are often used in combination with CIPC. These naphthalene products most likely suppress sprouts by hormonal action and provide mild sprout control. Other products available for sprout control in storage are chemicals that physically damage the sprout and therefore need to be applied on a regular or continuous basis. Those products include clove oil (Biox C; Sprout Torch) and spearmint and peppermint oils. Cost, application methods, and long-term efficacy are considered by storage managers. Clove oil can be applied to commercial potatoes as a thermal aerosol while potatoes are in storage to minimize silver scurf, although research has shown multiple applications are necessary for even a slight reduction. There is currently no alternative to CIPC for long-term sprout suppression.

Some developing export markets, such as Japan, allow lower tuber residue levels of CIPC than would be present if used at some labeled rates. For this reason, alternative sprout inhibitors need to be developed.

The three basic tools of storage management, temperature, humidity, and airflow, help in managing many diseases in storage. There are limited post-harvest-applied products available that aid in the control and suppression of storage diseases in the potato industry. The two major product categories available are fungicides and general biocides or disinfestants. Primarily, only general biocides or disinfestants such as chlorine dioxide, hydrogen peroxide, and peroxyacetic acid (HPPA) mixtures (StorOx, Jet-Oxide, Tsunami), and ozone can be applied to potatoes for disease control once the potatoes are in storage. These products are typically applied through the humidification system. Application methodology problems and the high organic load associated with storing potatoes reduce the efficacy of these disinfestants. No disinfestant will stop an established disease infection. Research results have shown very inconsistent and limited benefit with the use of these products on late blight, pink rot, dry rot, and silver scurf.

Late blight and **pink rot** have been commonly reported to cause destruction throughout entire storage lots. Pink rot can infect tubers that are wounded, but it can also infect undamaged tubers. While these diseases merely initiate the problems, infected tubers going into storage quickly rot due to bacteria. Rotting tubers cause adjacent tubers to become anaerobic, which can lead to rot. The process continues until large areas within the stored lot are impacted. Large volumes of air can minimize the disease progression.

Potatoes can be treated with a post-harvest fungicide or disinfestant as the potatoes are being loaded into the storage facility. Typically the products are applied as a low-pressure and low-volume spray to the potatoes as they are conveyed into the storage facility. The two major product categories available are fungicides and general biocides or disinfestants. If post-harvest products are employed, they must be used in combination with good basic storage management. There are several products registered, but they have shown minimal efficacy in research programs. There are limited post-harvest-applied products available that aid in the control and suppression of storage diseases in the potato industry. Only one post-harvest product, phosphorous acid, consistently demonstrates disease control for late blight and pink rot. Phosphorous acid (Phostrol, Fosphite, Resist 57, Crop-phite) is labeled for pink rot and late blight control and show excellent and consistent control when applied to potatoes going into storage.

Bacillus subtilis (Serenade) can also be applied to potatoes going into storage for silver scurf, although minimal efficacy data is available. A biological product, BioSave 10 LP (*Pseudomonas syringae*), is labeled but has shown limited control of dry rot and silver scurf when applied to potatoes entering storage. Thiabendazole (Mertect 340-F) is labeled for control of dry rot and silver scurf, but the pathogens causing these two diseases have developed fungicide resistance and it is no longer recommended for use.

General biocides or disinfestants available include chlorine dioxide, hydrogen peroxide and peroxyacetic acid (HPPA) mixtures (StorOx, Jet-Oxide, Tsunami), sodium hypochlorite, and calcium hypochlorite. Chlorine dioxide and HPPA mixtures can also be applied to potatoes in storage through the humidification system. Application methodology problems and the high organic load associated with storing potatoes reduce the efficacy of these disinfestants. No disinfestant will stop an established disease infection. Research results have shown very inconsistent and limited benefit with the use of these products on late blight, pink rot, dry rot, and silver scurf. Another product, ozone, can be applied at high concentrations for approximately 30 seconds using a tunnel apparatus as potatoes are entering the storage. Pacific Northwest research has not shown any benefit from applying ozone in this manner or through the ventilation system for controlling pink rot or silver scurf.

Other diseases that can become a problem in storage include Pythium leak, early blight, black dot, black scurf, and net necrosis. There are no products to manage these diseases. They are controlled by storage management.

Potato-rot nematode (*Ditylenchus destructor*), while not widely present in the PNW region, can cause devastating rot in stored tubers. High relative humidity is an essential factor for the establishment of this nematode. Control of this nematode takes place pre-plant and at planting, but the effect of nematodes manifests itself at harvest or storage, when infected tubers rot. This pest is not present in Washington or Oregon and is not widely present in Idaho.

As mentioned in the *Vine-Kill* and *Harvest* sections, tubers are especially vulnerable to **potato tuberworm** damage just prior to harvest. If tubers infected with tuberworm are put into storage, the larvae have the capacity to cause overwhelming economic damage. They excavate tunnels throughout the potato tuber, often leaving mounds of frass near the tunnel entrances. In addition to their physical damage to the tubers, the tunnels allow the introduction of bacteria and fungi into the tuber. There are no registered controls for potato tuberworm in storage. To detect this pest's presence, frequent checks of stored potatoes for signs of rot and insect damage must be made.

Critical Pest Management Needs in PNW Potatoes Post-Harvest

Research

- Develop chemicals and method of application for sprout suppression.
- Evaluate application methodology, rates, and chemistries of post-harvest products to minimize product residues.
- Investigate the effect of storage temperature on nematode and tuberworm development and damage in storage.
- Improve management of all storage diseases, such as Fusarium dry rot and silver scurf.
- Develop effective post-harvest products for disease control.
- Determine efficacy of lower rates of CIPC in conjunction with other products or management.

- Investigate need for tuberworm management in storage.
- Investigate storage management options for disease and sprout control.
- Develop a sprout inhibitor chemical that meets tolerances for foreign markets.

Regulatory

- Maintain tolerance for CIPC until viable economic alternative is available.
- Continue to support 24(c) registration for CIPC
- Support registration of new disease and sprout control products.

Education

- Educate growers on storage management practices (humidity, temperatures, air flow).
- Educate growers on seasonal effects on storage.
- Educate growers about the difference between wireworm and tuberworm damage.
- Educate growers about the timing of maleic hydrazide treatment according to potato variety.

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Activity Table for Eastern Idaho

Cultural Activities												
Activity	J	F	M	A	M	J	J	A	S	O	N	D
Bed prep			X	XXX	XX					XXX	XX	
Planting and drag-off				XX	XX	XX						
Fertilization			XXX	XXX	XXX	XXX	XX		XXX	XX	XX	
Hilling					XXX	XX						
Cultivation					XX	XX						
Irrigation					XX	XX	XXX	XX	X			
Vine-kill								XX	XX			
Harvest									XXX	XX		
Storage	XXX	XX	XX	XXX	XX	XX	XX		XXX	XXX	XX	XX

Pest Management Activities												
	J	F	M	A	M	J	J	A	S	O	N	D
Insecticide app.			X	XXX	XXX	XXX	XXX	XX				
Herbicide app.				XXX	XX	XX						
Fungicide app.						XX	XXX	XX				
Aerial monitoring	XXX	XX	XX	XXX	XX	XX	XXX	XX				
Soil and water analysis		XX	XX	XXX	XX							
Soil sampling for nematodes			X	XXX	XX	XX	XXX	XX	XXX	XXX		
Weed surveys					XX	XX	XXX	XXX	XXX			
Monitor for wireworms			XX			XXX	XX	XX				
Keep weather records	XXX	XX	XX	XXX	XX	XX	XXX	XX	XX	XXX		
Petiole nutrient analysis					X	XXX	XXX	XXX				
Keep water budget			XXX	XX	XX	XXX	XX	XX	XXX			
Monitor soil moisture			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX		
Monitor soil temperature			X	XXX	XXX	X			X	XXX		
Monitor weed emergence				XXX	XX	XX	XXX	XX	XX			
Monitor for aphids						XXX	XX	XXX	XX			
Monitor for early blight and late blight						X	XX	XXX	XX	XX		
Monitor canopy moisture, temperature, and humidity					XXX	X	XX	XXX	X			
Monitor temperature and humidity	XXX	XX	XX	XXX	XX	XX				XXX	XX	XX

Seasonal Pest Occurrence for Eastern Idaho

Weeds		J	F	M	A	M	J	J	A	S	O	N	D
Barnyardgrass	Present#			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
	Treated*				XXX	XXX	XXX						
Common lambsquarters	Treated					XXX	XXX	XXX					
	Treated					XXX	XXX	XXX					
Grasses	Present				XXX	XXX	XXX	XXX	XXX	XXX	XXX		
	Treated				XXX	XXX	XXX						
Green foxtail	Present				XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX						
Kochia	Present			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX						
Nightshade, cutleaf	Present					XXX	XXX	XXX	XXX	XXX			
	Treated					XXX	XXX						
Nightshade, hairy	Present				XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX			XXX			
Pigweed, redroot	Present				XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX						
Volunteer grain	Treated			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
	Present			XXX	XXX	XXX	XXX						
Wild oats	Treated					XXX	XXX	XXX	XXX	XXX			
	Treated					XXX	XXX						
Diseases		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bacterial soft rot	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated	No Treatment											
Early blight	Present						XXX	XXX	XXX	XXX			
	Treated						XXX	XXX	XXX	XXX			
Early die/Vert	Present				seed	seed		XXX	XXX	XXX			
	Treated						XXX	XXX	XXX	XXX			
Fusarium dry rot	Present				seed	seed					XXX	XXX	XXX
	Treated				XXX	XXX					XXX	XXX	XXX
Late blight	Present				seed	seed	XXX	XXX	XXX	XXX	XXX		
	Treated				XXX	XXX	XXX	XXX	XXX	XXX	XXX		
Potato leaf roll virus	Present				seed	seed		XXX	XXX	XXX	XXX		
	Treated				XXX	XXX	XXX	XXX	XXX	XXX	XXX		
Pink rot (+ storage)	Present							XXX	XXX	XXX	XXX	XXX	XXX
	Treated				XXX	XXX	XXX	XXX	XXX				
Pythium leak	Present	XXX	XX	XX	XXX	XXX	XX				XXX	XX	XX
	Treated												
Rhizoctonia stem canker (Black scurf)	Present					XXX	XXX	XXX	XXX	XXX			
	Treated				XXX					XXX	XXX		

Seasonal Pest Occurrence for Eastern Idaho, cont.

Seed piece decay	Present				XXX	XXX	XXX						
	Treated				XXX	XXX	XXX						
Silver scurf	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated				XXX	XXX							
White mold	Present							XXX	XXX				
	Treated							XXX	XXX				
Nematodes		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root-knot nematode	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated				XXX	XXX	XXX	XXX	XXX	XXX	XXX		
Root-lesion nematode	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated				XXX	XXX	XXX	XXX	XXX	XXX	XXX		
Stubby-root nematode	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated				XXX	XXX				XXX	XXX		
Insects		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Colorado potato beetles	Present						XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX	XXX					
Green peach aphids	Present						XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX	XXX	XXX	XXX			
Flea beetles	Present												
	Treated												
Potato tuberworm	Present	**Not Yet Present**											
	Treated												
Wireworms	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated				XXX	XXX	XXX			XXX	XXX		
Vertebrate Pests		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Vole	Present							XXX	XXX	XXX			
	Treated												

# Indicates periods when pests occur in fields. Population densities may or may not reach treatable levels. This ***DOES*** indicate the mere presence of pests in a field.

* When field activities are likely. This ***DOES NOT*** indicate the mere presence of pests in a field (e.g., perennial weeds and some insect and nematode pests may be found in fields all year, but management activities only occur as indicated in the table).

Activity Table for the Magic Valley

Cultural Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Bed prep			XXX	XXX	XXX				XX	XXX	XXX	X
Planting and drag-off			XX	XXX	XXX	XXX						
Fertilization			XXX	XXX	XXX	XXX	XXX	XX	XX	XXX	XXXX	
Hilling				XX	XXX	XX						
Cultivation				XX	XXX	XX						
Irrigation					XX	XXX	XXX	XXX	XXX	XX		
Vine-kill							XX	XXX	XXX	X		
Harvest							XX	XXX	XXX	XX		
Storage	XXX	XXX	XXX	XXX	XXX	XXX	XX		XX	XXX	XXX	XXX

Pest Management Activities

	J	F	M	A	M	J	J	A	S	O	N	D
Insecticide app.			XX	XXX	XXX	XXX	XXX	XXX				
Herbicide app.			XX	XXX	XXX	XX						
Fungicide app.			XX	XXX	XXX	XX	XXX	XXX	XXX			
Nematicide/fumigation			XXX	XXX	XXX				XXX	XXX		
Seed treatment			XX-	XXX	XX-							
Aerial monitoring	XXX	XXX	XXX	XXX	XXX	XX	XXX	XXX	XXX			
Soil and water analysis			XXX	XXX			XX	XXX	XXX	XXX	XXX	
Soil sampling for nematodes			XXX	XXX					XX-	XXX	XXX	
Weed surveys				XXX	XXX	XXX	XXX	XXX	XXX			
Monitor for wireworms								XXX	XXX			
Keep weather records			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX		
Petiole nutrient analysis						XXX	XXX	XXX				
Keep water budget					XXX	XXX	XXX	XXX	XXX			
Monitor soil moisture			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX		
Monitor soil temperature			XXX	XXX	XXX	XXX	XXX	XXX	XX	XXX		
Monitor weed emergence				XXX	XXX	XXX	XXX	XXX	XXX	XXX		
Monitor for aphids					XXX	XXX	XXX	XXX	XXX			
Monitor for early blight and late blight	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Monitor canopy moisture, temperature and humidity					XXX	XXX	XXX	XXX	XXX			
Monitor temperature and humidity (storage)	XXX	XXX	XXX	XXX	XXX	XXX	XXX		XXX	XXX	XXX	XXX

Seasonal Pest Occurrence Table for the Magic Valley

Weeds		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Barnyardgrass	Present#			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
	Treated*				XXX	XXX	XXX						
Common lambsquarters	Treated				XXX	XXX	XXX	XXX	XXX	XXX			
	Present				XXX	XXX	XXX						
Grasses	Present				XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX						
Green foxtail	Present				XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX						
Kochia	Present			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX						
Nightshade, hairy	Present				XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX			XXX			
Pigweed, redroot	Present				XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX						
Quackgrass	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated				XXX	XXX	XXX			XXX	XXX		
Volunteer grain	Treated			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
	Present			XXX	XXX	XXX	XXX						
Volunteer potatoes	Present				XXX	XXX	XXX	XXX	XXX	XXX	XXX		
	Treated				XXX	XXX	XXX		XXX	XXX			
Wild oats	Treated				XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX						
Diseases		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bacterial soft rot	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated	No Treatment											
Black dot	Present							XXX	XXX	XX			
	Treated												
Early blight	Present							XXX	XXX	XXX			
	Treated					XXX	XXX	XXX	XXX	XXX			
Early die/Vert	Present				seed	seed		XXX	XXX	XXX			
	Treated			XXX	XXX		XXX	XXX	XXX	XXX	XXX	XXX	
Fusarium dry rot	Present	XXX	XXX	XXX	XXX				XXX	XXX	XXX	XXX	XXX
	Treated			XXX	XXX					XXX	XXX		
Late blight	Present			seed	seed	seed		XXX	XXX	XXX			
	Treated			XXX	XXX		XXX	XXX	XXX	XXX			
Potato leaf roll virus	Present			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated			XXX	XXX	XXX	XXX	XXX					
Pink rot (+ storage)	Present								XX	XXX	XXX	XXX	XXX
	Treated					XXX	XXX	XXX	XXX	XXX			

Seasonal Pest Occurrence Table for the Magic Valley, cont.

Pythium leak	Present								XX	XXX	XXX	XXX	XXX
	Treated	No Treatment											
Rhizoctonia stem canker (Black scurf)	Present			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
	Treated			XXX	XXX	XXX							
Seed piece decay	Present			XX	XXX	XXX	XXX						
	Treated			XXX	XXX	XXX							
Silver scurf	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX		XXX	XXX	XXX	XXX
	Treated			XXX	XXX								
White mold	Present							XXX	XXX				
	Treated						XXX	XXX	XXX				
Nematodes		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root-knot nematode	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX	XXX	XXX	XXX
	Treated		XXX	XXX	XXX	XXX			XXX	XX	XXX	XXX	
Root-lesion nematode	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX	XXX	XXX	XXX
	Treated		XXX	XXX	XXX	XXX			XXX	XX	XXX	XXX	
Stubby-root nematode	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX	XXX	XXX	XXX
	Treated		XXX	XXX	XXX	XXX			XXX	XX	XXX	XXX	
Insects		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Green peach aphids	Present						XXX	XXX	XXX	XXX			
	Treated			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Colorado potato beetles	Present						XX	XXX	XXX				
	Treated			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Wireworms	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated			XXX	XXX	XXX				XXX	XXX	XXX	
Worms	Present						XXX	XXX	XXX				
	Treated					XXX	XXX	XXX	XXX				
Vertebrate Pests		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Vole	Present							XXX	XXX	XXX	XXX		
	Treated												

# Indicates periods when pests occur in fields. Population densities may or may not reach treatable levels. This ***DOES*** indicate the mere presence of pests in a field.

* When field activities are likely. This ***DOES NOT*** indicate the mere presence of pests in a field (e.g., perennial weeds and some insect and nematode pests may be found in fields all year, but management activities only occur as indicated in the table).

Activity Table for Southeastern Idaho

Cultural Activities												
Activity	J	F	M	A	M	J	J	A	S	O	N	D
Bed prep			XXX	XXX	XXX					XXX	XXX	
Planting and drag-off				XXX	XXX	XXX						
Fertilization			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	
Hilling				XXX	XXX	XXX						
Cultivation					XXX	XXX						
Irrigation				XXX	XXX	XXX	XXX	XXX	XXX			
Vine-kill								XXX	XXX			
Harvest								XXX	XXX	XXX		
Storage	XXX	XXX	XXX	XXX	XXX	XXX	XXX		XXX	XXX	XXX	XXX

Pest Management Activities												
	J	F	M	A	M	J	J	A	S	O	N	D
Insecticide app.				XXX	XXX	XXX	XXX	XXX	XXX			
Herbicide app.				XXX	XXX	XXX						
Fungicide app.				XXX	XXX	XXX	XXX	XXX	XXX			
Aerial monitoring				XXX	XXX	XXX	XXX	XXX				
Soil, water analysis			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	
Soil sampling for nematodes			XXX	XXX	XXX			XXX	XXX	XXX		
Weed surveys			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Monitor for wireworms				XXX	XXX							
Keep weather records	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Petiole nutrient analysis						XXX	XXX	XXX				
Keep water budget						XXX	XXX	XXX	XXX			
Monitor soil moisture				XXX	XXX	XXX	XXX	XXX	XXX			
Monitor soil temperature				XXX	XXX				XXX	XXX	XXX	
Monitor weed emergence			XXX	XXX	XXX	XXX						
Monitor for aphids						XXX	XXX	XXX	XXX			
Monitor for early blight and late blight						XXX	XXX	XXX	XXX			
Monitor canopy moisture, temperature, and humidity						XXX	XXX	XXX	XXX			
Monitor temperature and humidity			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX		

Seasonal Pest Occurrence for Southeastern Idaho

Weeds		J	F	M	A	M	J	J	A	S	O	N	D
Barnyardgrass	Present#					XXX	XXX	XXX	XXX	XXX			
	Treated*					XXX	XXX	XXX					
Common lambsquarters	Treated					XXX	XXX	XXX	XXX	XXX			
	Present					XXX	XXX	XXX					
Kochia	Present			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX	XXX					
Grasses	Present					XXX	XXX	XXX	XXX	XXX	XXX		
	Treated					XXX	XXX	XXX			XXX		
Green foxtail	Present					XXX	XXX	XXX	XXX	XXX			
	Treated					XXX	XXX	XXX					
Nightshade, cutleaf	Present					XXX	XXX	XXX	XXX	XXX			
	Treated					XXX	XXX						
Nightshade, hairy	Present					XXX	XXX	XXX	XXX	XXX			
	Treated					XXX	XXX	XXX		XXX			
Pigweed, redroot	Present					XXX	XXX	XXX	XXX	XXX			
	Treated					XXX	XXX	XXX	XXX				
Volunteer grain	Present				XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX	XXX					
Volunteer potatoes	Present				XXX	XXX	XXX	XXX	XXX	XXX	XXX		
	Treated				XXX	XXX	XXX		XXX	XXX			
Wild oats	Present					XXX	XXX	XXX	XXX	XXX			
	Treated					XXX	XXX	XXX		XXX			
Diseases		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bacterial soft rot	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated	No Treatment											
Early blight	Present						XXX	XXX	XXX	XXX			
	Treated						XXX	XXX	XXX	XXX			
Early die/Vert	Present				seed	seed		XXX	XXX	XXX			
	Treated						XXX	XXX	XXX	XXX			
Fusarium dry rot	Present				seed	seed					XXX	XXX	XXX
	Treated				XXX	XXX					XXX	XXX	XXX
Late blight	Present				seed	seed	XXX	XXX	XXX	XXX	XXX		
	Treated				XXX	XXX	XXX	XXX	XXX	XXX	XXX		
Potato leaf roll virus	Present				seed	seed		XXX	XXX	XXX	XXX		
	Treated				XXX	XXX	XXX	XXX	XXX	XXX	XXX		
Pink eye	Present								XXX	XXX	XXX		
	Treated	No Treatment											
Pink rot (+ storage)	Present							XXX	XXX	XXX	XXX	XXX	XXX
	Treated				XXX	XXX	XXX	XXX	XXX				
Pythium leak	Present									XXX	XXX	XXX	
	Treated	No Treatment											

Seasonal Pest Occurrence for Southeastern Idaho, cont.

Rhizoctonia stem canker (Black scurf)	Present					XXX	XXX	XXX	XXX	XXX			
	Treated				XXX					XXX	XXX		
Seed piece decay	Present				XXX	XXX	XXX						
	Treated				XXX	XXX	XXX						
Silver scurf	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated				XXX	XXX							
White mold	Present							XXX	XXX	XXX			
	Treated							XXX	XXX				
Nematodes		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root-knot nematode	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated				XXX	XXX	XXX	XXX	XXX	XXX	XXX		
Root-lesion nematode	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated				XXX	XXX	XXX	XXX	XXX	XXX	XXX		
Stubby-root nematode	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated				XXX	XXX				XXX	XXX		
Insects		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Armyworms	Present					XXX	XXX						
	Treated					XXX	XXX						
Colorado potato beetles	Present						XXX	XXX	XXX				
	Treated				XXX	XXX	XXX	XXX					
Crane Fly	Present						XXX	XXX	XXX				
	Treated	No Treatment											
Grasshoppers	Present						XXX	XXX	XXX				
	Treated							XXX					
Green peach aphids	Present						XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX	XXX	XXX	XXX			
Leafhoppers	Present							XXX	XXX				
	Treated							XXX	XXX				
Loopers	Present							XXX	XXX				
	Treated							XXX	XXX				
Potato Tuberworm	Present	**Not Yet Present**											
	Treated												
Wireworms	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated				XXX	XXX	XXX			XXX	XXX		
Vertebrate Pests		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Voles	Present							XXX	XXX	XXX	XXX		
	Treated								XXX	XXX			

# Indicates periods when pests occur in fields. Population densities may or may not reach treatable levels. This ***DOES*** indicate the mere presence of pests in a field.

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Activity Table for the Treasure Valley

Cultural Activities												
Activity	J	F	M	A	M	J	J	A	S	O	N	D
Bed prep		XXX	XXX	XXX				XXX	XXX	XXX	XXX	
Planting and drag-off			XXX	XXX	XXX							
Fertilization		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	
Hilling				XXX	XXX							
Cultivation				XXX	XXX							
Irrigation				XXX	XXX	XXX	XXX	XXX	XXX	XXX		
Vine-kill							XXX	XXX	XXX	XXX		
Harvest							XXX	XXX	XXX	XXX	XXX	
Storage	XXX	XXX	XXX	XXX	XXX	XXX	XXX		XXX	XXX	XXX	XXX

Pest Management Activities												
	J	F	M	A	M	J	J	A	S	O	N	D
Insecticide app.			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Herbicide app.			XXX	XXX	XXX	XXX						
Fungicide app.			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Fumigants		XXX	XXX					XXX	XXX	XXX	XXX	XXX
Aerial monitoring					XXX	XXX	XXX	XXX				
Soil and water analysis		XXX	XXX	XXX				XXX	XXX	XXX		
Soil sampling for nematodes		XXX	XXX					XXX	XXX	XXX		
Weed surveys						XXX	XXX					
Monitor for wireworms			XXX	XXX	XXX				XXX	XXX		
Keep weather records	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Petiole nutrient analysis					XXX	XXX	XXX	XXX	XXX			
Keep water budget												
Monitor soil moisture			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX		
Monitor soil temperature		XXX	XXX	XXX								
Monitor weed emergence			XXX	XXX	XXX	XXX						
Monitor for aphids						XXX	XXX	XXX	XXX			
Monitor for early blight and late blight					XXX	XXX	XXX	XXX	XXX			
Monitor canopy moisture, temperature and humidity					XXX	XXX	XXX	XXX	XXX			
Monitor temperature and humidity (storage)	XXX	XXX	XXX	XXX	XXX	XXX	XXX		XXX	XXX	XXX	XXX

Seasonal Pest Occurrence for the Treasure Valley

Weeds		J	F	M	A	M	J	J	A	S	O	N	D
Barnyardgrass	Present#					XXX	XXX	XXX	XXX				
	Treated*			XXX	XXX	XXX	XXX			XXX	XXX	XXX	
Common lambsquarters	Present				XXX	XXX	XXX	XXX	XXX	XX			
	Treated				XXX	XXX	XXX						
Grasses	Present			XXX	XXX	XXX	XXX	XXX	XXX	XX			
	Treated			XXX	XXX	XXX	XXX			XXX	XXX	XXX	
Green foxtail	Present					XXX	XXX	XXX					
	Treated			XXX	XXX	XXX	XXX			XXX	XXX	XXX	
Kochia	Present			XXX	XXX	XXX	XXX	XXX	XXX	XX			
	Treated			XXX	XXX	XXX	XXX			XXX	XXX	XXX	
Nightshade, hairy	Present			XXX	XXX	XXX	XXX	XXX	XXX	XX			
	Treated			XXX	XXX	XXX	XXX		XXX	XXX			
Nutsedge, yellow	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	
	Treated					XXX	XXX						
Pigweed, redroot	Present			XXX	XXX	XXX	XXX	XXX	XXX	XX			
	Treated			XXX	XXX	XXX				XXX	XXX	XXX	
Volunteer grain	Treated			XXX	XXX	XXX	XXX	XXX	XXX	XX			
	Present			XXX	XXX	XXX	XXX						
Wild oats	Present					XXX	XXX	XXX					
	Treated			XXX	XXX	XXX	XXX			XXX	XXX	XXX	
Volunteer potatoes	Present			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX		
	Treated			XXX	XXX	XXX	XXX		XXX	X			
Diseases		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bacterial soft rot	Present					XXX	XXX	XXX					
	Treated	No Treatment											
Early blight	Present					XXX	XXX	XXX	XXX	XXX			
	Treated					XXX	XXX	XXX	XXX	XXX			
Early die/Vert	Present			seed	seed			XXX	XXX	XXX	XXX	XXX	
	Treated			XXX	XXX		XXX	XXX	XXX	XXX	XXX	XXX	
Fusarium dry rot	Present	XXX	XXX	XXX	XXX					XXX	XXX	XXX	XXX
	Treated			XXX	XXX					XXX	XXX		
Late blight	Present			seed	seed		XXX	XXX	XXX	XXX			
	Treated			XXX	XXX		XXX	XXX	XXX	XXX			
Potato leaf roll virus	Present				XXX	XXX	XXX	XXX					
	Treated			XXX	XXX	XXX	XXX	XXX					
Pink rot (+ storage)	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
	Treated					XXX	XXX	XXX	XXX	XXX			
Pythium leak	Present									XXX	XXX		
	Treated	No Treatment											

Seasonal Pest Occurrence for the Treasure Valley, cont.

Rhizoctonia stem canker (Black scurf)	Present				XXX	XXX	XXX	XXX	XXX	XXX	XXX		
	Treated			XXX	XXX	XXX							
Seed piece decay	Present			XXX	XXX	XXX							
	Treated			XXX	XXX	XXX							
Silver scurf	Present	XXX	XXX	XXX	XXX						XXX	XXX	XXX
	Treated			XXX	XXX								
White mold	Present							XXX	XXX	XXX			
	Treated						XXX	XXX	XXX				
Nematodes		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root-knot nematode	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX	XXX	XXX	XXX
	Treated		XXX	XXX	XXX	XXX			XXX	XX	XXX	XXX	
Root-lesion nematode	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX	XXX	XXX	XXX
	Treated		XXX	XXX	XXX	XXX			XXX	XX	XXX	XXX	
Stubby-root nematode	Present	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX	XXX	XXX	XXX
	Treated		XXX	XXX	XXX	XXX			XXX	XX	XXX	XXX	
Insects		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Colorado potato beetles	Present				XXX	XXX	XXX	XXX	XXX	XXX			
	Treated			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Green peach aphids	Present						XXX	XXX	XXX	XXX			
	Treated			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Flea beetles	Present				XXX	XXX							
	Treated			XXX	XXX	XXX							
Potato tuberworm	Present					XXX	XXX	XXX	XXX	XXX			
	Treated					XXX	XXX	XXX	XXX	XXX			
Spider mites	Present						XXX	XXX	XXX	XXX			
	Treated						XXX	XXX	XXX	XXX			
Symphylans	Present			XXX	XXX	XXX							
	Treated			XXX	XXX					XXX	XXX	XXX	
Wireworms	Present			XXX	XXX	XXX	XXX						
	Treated			XXX	XXX	XXX				XXX	XXX	XXX	
Worms	Present					XXX	XXX	XXX	XXX				
	Treated					XXX	XXX	XXX	XXX				
Vertebrate Pests		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Vole	Present						XXX	XXX	XXX	XXX	XXX	XXX	
	Treated			XXX	XXX	XXX	XXX	XXX	XXX				

# Indicates periods when pests occur in fields. Population densities may or may not reach treatable levels. This ***DOES*** indicate the mere presence of pests in a field.

* When field activities are likely. This ***DOES NOT*** indicate the mere presence of pests in a field (e.g., perennial weeds and some insect and nematode pests may be found in fields all year, but management activities only occur as indicated in the table).

Activity Table for Oregon and Washington West of the Cascades

Cultural Activities												
Activity	J	F	M	A	M	J	J	A	S	O	N	D
Bed prep				XXX	XXX	XXX						
Planting and drag-off				XXX	XXX	XXX						
Fertilization				XXX	XXX	XXX						
Hilling					XXX	XXX	XXX					
Cultivation					XXX	XXX	XXX					
Irrigation					XXX	XXX	XXX	XXX	XXX			
Vine-kill								XXX	XXX			
Harvest							XXX	XXX	XXX	XXX		
Storage	XXX	XXX	XXX	XXX					XXX	XXX	XXX	XXX

Pest Management Activities												
	J	F	M	A	M	J	J	A	S	O	N	D
Insecticide app.				XXX	XXX	XXX	XXX	XXX				
Herbicide app.				XXX	XXX	XXX						
Fungicide app.					XXX	XXX	XXX	XXX	XXX			
Aerial monitoring												
Soil and water analysis			XXX	XXX	XXX							
Soil sampling for nematodes												
Weed surveys					XXX	XXX						
Monitor for wireworms	Mostly practiced by organic growers for citing fields.								XXX	XXX		
Keep weather records												
Petiole nutrient analysis	Generally once per season only.					XXX	XXX					
Keep water budget												
Monitor soil moisture						XXX	XXX	XXX	XXX			
Monitor soil temperature												
Monitor weed emergence				XXX	XXX	XXX						
Monitor for aphids	No seed production in Western Oregon, only casual aphid monitoring taking place.											
Monitor for early blight and late blight					XXX	XXX	XXX	XXX	XXX			
Monitor canopy moisture, temperature, and humidity	Growers invariably have to spray for late blight, so monitoring canopy moisture is not really useful in this region in that it is not predicative of late blight occurrence.											
Monitor temperature and humidity												
Monitor temperature and humidity (storage)	XXX	XXX	XXX	XXX	XXX				XXX	XXX	XXX	XXX

Seasonal Pest Occurrence for Oregon and Washington West of the Cascades

Weeds		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Chickweed	Present#	Can be problematic in this region.											
	Treated*												
Common lambsquarters	Present				XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX						
Grasses	Present				XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX	XXX					
Kochia	Present			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX	XXX					
Nightshade, hairy	Present				XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX	XXX	XXX	XXX			
Pigweed, redroot	Present				XXX	XXX	XXX	XXX	XXX	XXX			
	Treated				XXX	XXX	XXX	XXX					
Purslane	Present	Can be problematic in this region.											
	Treated												
Diseases		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bacterial soft rot	Present	XXX	XXX	XXX	XXX	XXX	XXX					XXX	XXX
	Treated				XXX	XXX	XXX						
Early blight	Present	Generally controlled along with treatments for late blight.						XXX	XXX	XXX			
	Treated					XXX	XXX	XXX	XXX	XXX			
Early die/Verticillium wilt	Present								XXX	XXX			
	Treated												
Fusarium dry rot	Present				XXX	XXX	XXX						
	Treated				XXX	XXX	XXX						
Late blight	Present						XXX	XXX	XXX	XXX	XXX		
	Treated					XXX	XXX	XXX	XXX	XXX			
Potato leaf roll virus	Present						XXX	XXX	XXX				
	Treated						XXX	XXX	XXX				
Pink rot (+ storage)	Present								XXX	XXX			
	Treated												
Pythium leak	Present								XXX	XXX			
	Treated	Managed as part of a seed treatment program.											
Rhizoctonia stem canker (black scurf)	Present					XXX	XXX	XXX	XXX				
	Treated												
Seed piece decay	Present				XXX	XXX	XXX						
	Treated				XXX	XXX	XXX						
Silver scurf	Present									XXX	XXX	XXX	
	Treated	Treatment is via storage mangement only, not chemicals.											
White mold	Present								XXX	XXX			
	Treated												
Nematodes		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root-knot nematode	Present												
	Treated												

Seasonal Pest Occurrence for Oregon and Washington West of the Cascades, cont.

Root-lesion nematode	Present												
	Treated												
Stubby-root nematode	Present												
	Treated												
Insects		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Colorado potato beetles	Present												
	Treated												
Green peach aphids	Present					XXX	XXX	XXX	XXX				
	Treated				XXX	XXX	XXX	XXX					
Potato tuberworm	Present	Not yet a problem in this region.											
	Treated												
Symphylans	Present				XXX	XXX	XXX						
	Treated												
Tuber fleabeetles	Present				XXX	XXX	XXX	XXX					
	Treated				XXX	XXX	XXX	XXX					
Western spotted cucumber beetle	Present							XXX	XXX				
	Treated												
Wireworms	Present				XXX	XXX	XXX						
	Treated												
Vertebrate Pests		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Vole	Present				XXX	XXX	XXX	XXX	XXX	XXX			
	Treated												

# Indicates periods when pests occur in fields. Population densities may or may not reach treatable levels. This ***DOES*** indicate the mere presence of pests in a field.

* When field activities are likely. This ***DOES NOT*** indicate the mere presence of pests in a field (e.g., perennial weeds and some insect and nematode pests may be found in fields all year, but management activities only occur as indicated in the table).

Efficacy Table for Nematode Management in PNW Potatoes

This table is a compilation of information concerning the efficacy of various compounds and practices on potato nematode pests. Presence in the table is not an indication of registration for specific pests, although we have indicated their general registration on potatoes. The tables compare the relative efficacy of available and potential products for each pest, thereby indicating where research and registration efforts are needed.

	root-knot nematode	root-lesion nematode	stubby-root nematode	potato cyst nematode	potato-rot nematode*	Comments
Registered Materials						
1,3-dichloropropene (Telone II)	G	G	G	G		No applications have been made for PCN.
aldicarb (Temik)	G-E	G-E	G-E	G		No applications have been made for PCN.
chloropicrin + 1,3-dicloropropene (Telone C-17)				G		
ethoprop (Mocap)	F-G	F-G	P	P		Used in combination with fumigants for RKN & RLN.
metam-based products (Vapam, Metam, Busan)	G	G	P	P		
methyl bromide	E	E	E	E		No applications have been made yet. There is no in-field registration for methyl bromide on potatoes. EPA is phasing out this product. Currently, applicators in the region do not have the required equipment to use this product.
oxamyl (Vydate)	F-G	G-E	G-E	P		
Biologicals and others						
Myrothecium verrucaria strain AARC-0255 (DiTera WDG)						
Pipeline Materials and Possible Biologicals						
fosthiazate	G	G	G			
Hirsutella rhossiliensis	X	X	X			
Rhizobium etli G12	X			X		
IPM and Cultural Controls						
avoiding contaminated water for irrigation	X	X	X	X		
avoiding nondecomposed manure	X	X	X	X		
catch crops (oil radish and rapeseed green manure crops)	X	X	X			
crop rotation	X	X	X	X		
early harvest	X	X	X			
fallowing	X	X	X	X		
irrigation management	X	X	X			
sanitation measures	X	X	X	X	X	
tillage to reduce crop residue	X	X	X			
use of healthy/certified seed	X	X	X	X	X	
use of organic manure	X	X	X			
weed/alternate host control	X	X	X			

Efficacy rating symbols: E = Excellent (90-100% control), G = Good (80-89% control), F = Fair (70-79% control), P = Poor (<70% control), X = This control is used and is believed to have some efficacy against this pest but is likely not a stand-alone method.

* No chemical treatments specifically directed at PRN.

Efficacy Table for Disease Management in PNW Potatoes

This table is a compilation of information concerning the efficacy of various compounds and practices on potato diseases in the PNW. Does not indicate registration for specific pests, although we have indicated their general registration on potato. The tables compare the relative efficacy of available and potential products for each pest, thereby indicating where research and registration efforts are needed.

	In the Field																	In Storage					
	soil fumigant	Fusarium seed piece decay	early blight	late blight	early die (Verticillium wilt)	potato leaf roll virus	silver scurf	bacterial stem rot	*Fusarium*	*Botrytis*	powdery scab	powdery mildew	seed-borne common scab	blackleg	ring rot	white mold	black scurf (Rhizoctonia stem canker)	black dot	pink rot	Pythium leak	Fusarium dry rot	early blight	late blight	Comments, Other Products with Same Active Ingredient
Registered Fungicides																								
1,3 dichloropropene (Telone II)					G																			
azoxystrobin (Amistar, Quadris)			E	F			F					F					G	F						
azoxystrobin + chlorothalonil (Quadris Opti)																		F						
boscalid (Endura)			E													E								
chlorothalonil-based products (Bravo, Echo, Equus, Terranil)			G	G						X		P*												Ridomil Gold Bravo (chlorothalonil + metalaxyl-M); Bravo S (chlorothalonil + sulfur) *Applies to Bravo S only
copper-based products			P	P				P																
copper salts of fatty & rosin acids (Tenn-Cop)			P	P				P																
cyazofamid (Ranman)				E					G															
cymoxanil-based products (Curzate)				E																				Evolve (cymoxanil + mancozeb, thiophanate-methyl)
dazomet (Basamid)	X																							
dicloran (Botran, DCNA)																F								
dimethomorph (Acrobat)				E																				
ethylenebisdithiocarbamate (EBDC)				G																				
famoxadone (Tanos)			E	E														F						
fenamidone (Reason)			E	E														F						

Efficacy Table for Disease Management in PNW Potatoes, cont.

	In the Field																		In Storage					Comments, Other Products with Same Active Ingredient
	soil fumigant	Fusarium seed piece decay	early blight	late blight	early die (Verticillium wilt)	potato leaf roll virus	silver scurf	bacterial stem rot	*Fusarium*	*Botrytis*	powdery scab	powdery mildew	seed-borne common scab	blackleg	ring rot	white mold	black scurf (Rhizoctonia stem canker)	black dot	pink rot	Pythium leak	Fusarium dry rot	early blight	late blight	
fentin hydroxide (Agri Tin, Super Tin)				F																				
fluazinam (Omega)				E							P					E								
fludioxonil-based products (Maxim)							G**		E								G				N			Maxim MZ (fludioxonil + mancozeb) if seed-borne; **If seed-borne.
flutolanil-based products (Moncut)							G		G								G							Moncoat (flutalonil + mancozeb)
iprodione (Rovral)			P													F								
mancozeb-based products (Manzate, Dithane, Mankocide, Penncozeb)†		G	G	G			P						P-N											
maneb (Maneb, Manex)			G	G																				
mefenoxam-based products (Ridomil, Ultra Flourish)‡																			G	G				
metam-based products (K-pam, Vapam)					G																			
metiram (Polyram)			G	G																				
neem oil (Trilogy)																								fungal diseases
PCNB (pentachloronitrobenzene) (Blocker, PCNB 2E)													F			F	G	F						
peroxyacetic acid + hydrogen peroxide (Oxidate)				N			N												P				P	
phosphites, mono- and dibasic sodium, potassium, and ammonium (Phostrol)																			E	P			E	
potassium bicarbonate (Kaligreen, Armicarb)												F												
potassium phosphite (Prophyt)																			G	P			G	
propamocarb hydrochloride (Previcur Flex)			N	E																				
pyraclostrobin (Headline, Cabrio)			E	F														F						
pyrimethanil (Scala)			E							X														

Efficacy Table for Disease Management in PNW Potatoes, cont.

	In the Field																		In Storage					Comments, Other Products with Same Active Ingredient
	soil fumigant	Fusarium seed piece decay	early blight	late blight	early die (Verticillium wilt)	potato leaf roll virus	silver scurf	bacterial stem rot	*Fusarium*	*Botrytis*	powdery scab	powdery mildew	seed-borne common scab	blackleg	ring rot	white mold	black scurf (Rhizoctonia stem canker)	black dot	pink rot	Pythium leak	Fusarium dry rot	early blight	late blight	
streptomycin sulfate (Agri-Mycin)								X						X										
sulfur (many products)				P								G												
thiabendazole (Mertect, TBZ)																	N				F			Resistance issues
thiophanate-methyl (Topsin M, Tops MZ)§		G		G																				
trifloxystrobin (Flint, Gem)			G	G																				
trimethylammonium chloride															G									
triphenyltin hydroxide (Super Tin)			G	G																				
zoxamide (Gavel)			G	E																				Gavel also contains EBDC
Section 24(c) Products (WA)																								
dicloran (Botran 5F)																F								
flutolanil (Moncut)																	G							Labeled for in-furrow in ID
PCNB (Blocker)																F	G							
Section 18 Products (WA & ID)																								
chlorine dioxide (Purogene, Anthium 200)				P			P												P				P	
Biologicals and Others																								
Bacillus subtilis strain QST 713 (Serenade)	Some efficacy on post harvest silver scurf. Also registered for foliar application for early blight and late blight control.																							
Bacillus pumilis strain QST 2808 (Sonata)	Registered for post-harvest (non-stored) and foliar treatment for early blight, late blight, and powdery mildew. Efficacy unknown.																							
jojoba oil (E-rase Agriculture)	Registered for foliar treatment for powdery mildew. Efficacy unknown.																							
propylene glycol monocaprylate	Registered as a biopesticide for pre- and post-harvest application for control of diseases in storage. Efficacy unknown.																							
Pseudomonas syringae Strain ESC-11 (Bio-save)																					F			Also effective on post-harvest silver scurf.
Trichoderma harzianum Rifai strain KRL-AG2 (T-22, Rootshield)	Soil-applied to protect crop from root pathogens. Efficacy unknown.																							

Efficacy Table for Disease Management in PNW Potatoes, cont.

	In the Field																		In Storage					Comments, Other Products with Same Active Ingredient
	soil fumigant	Fusarium seed piece decay	early blight	late blight	early die (Verticillium wilt)	potato leaf roll virus	silver scurf	bacterial stem rot	*Fusarium*	*Botrytis*	powdery scab	powdery mildew	seed-borne common scab	blackleg	ring rot	white mold	black scurf (Rhizoctonia stem canker)	black dot	pink rot	Pythium leak	Fusarium dry rot	early blight	late blight	
Pipeline/Possible Biologicals and Other Materials																								
Ampelomyces quisqualis isolate M-10 (AQ10)	A naturally occuring hyperparasite of powdery mildews.																							
ethaboxam (Guardian)	Not registered in the United States, but there is an existing import tolerance for grapes. Suspected of being efficacious on late blight in potatoes.																							
iprovalicarb (Melody)	Registered on grapes. Suspected of being efficacious on late blight in potatoes.																							
Streptomyces lydicus WYEC 108	Applications as a soil mix are expected to control root decay fungi (e.g., *Fusarium, Rhizoctonia, Pythium,* others).																							
IPM and Cultural Control																								
adjust fertility/irrigation practices		X	X	X	X			X		X	X	X	X	X		X		X	X	X		X	X	
certified seed		X		X	X	X			X		X			X	X		X	X						Good for viruses.
control alternate hosts (weeds, other crops)				X	X	X										X								Good for viruses.
destroy cull potatoes				X		X																		Good for viruses.
field selection						X																		Good for viruses.
green manures					X												X	X						
proper rotation		X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X					
sanitation		X	X	X			X							X	X									
scouting			X	X	X			X		X		X				X			X	X	X	X	X	
remove decayed tubers coming into storage																			X	X			X	
spacing												X				X								
variety selection (resistance)				X	X	X																		Good for viruses.

Efficacy rating symbols: E = Excellent (90-100% control), G = Good (80-89% control), F = Fair (70-79% control), P = Poor (<70% control), N = None (no control), X = This control is used and is believed to have some efficacy against this pest but is likely not a stand-alone method.

† Acrobat MZ (mancozeb + dimethomorph), ManKocide (mancozeb + copper hydroxide), Maxim MZ (mancozeb + fludioxonil), Ridomil Gold MZ (mancozeb + metalaxyl-M), Tops MZ (mancozeb + thiophanate-methyl), Tops MZ Gaucho (mancozeb + thiophanate methyl + imidacloprid), Evolve (mancozeb + thiophanate-methyl + cymoxanil)

‡ Ridomil gold MZ (metalaxyl-M + mancozeb), Ridomil Gold Bravo (metalaxyl-M + chlorothalonil), Ridomil Gold Copper (metalaxyl-M + copper hydroxide), Platinum Ridomil Gold (metalaxyl-M + thiamethoxam)

§ Evolve (mancozeb + thiophanate-methyl + cymoxanil), Tops MZ (thiophanate-methyl + mancozeb), Tops MZ Gaucho (thiophanate-methyl + mancozeb + imidacloprid)

Efficacy Table for Insect Management in PNW Potatoes

This table is a compilation of information concerning the efficacy of various compounds and practices on insect and mite pests of potato. They are not an indication of registration for specific pests, although we have indicated their general registration status on potatoes. The tables compare the relative efficacy of available and potential products for each pest, thereby indicating where research and registration efforts are needed.

	green peach aphid	Colorado potato beetle	wireworm	symphylans	spider mites	lepidoptera	beet leafhoppers	Lygus bug	potato tuberworm	other	Comments
Registered Insecticides											
1,3-dichloropropene (Telone-II)			G	X							
abamectin (Agri-mek)		G			P				G-E		Application methods impractical. Priced too high.
acetamiprid (Assail)	G	G							F		
aldicarb (Temik)	G	G			G						It loses efficacy 65-80 days after planting (application).
carbaryl (Sevin)		G-E				G			P	Grasshoppers (G)	Excellent knock down. No residual. Bee concerns. One of few post-plant options.
carbofuran (Furadan)	P	G	P			F			G-E		
chloropicrin + 1,3-dicloropropene (Telone C-17)			G								
cryolite (Kryocide, Prokil)		F									
cyfluthrin (Baythroid XL)	F-P	E				G			G-E		Very cost effective. Not effective enough for seed protection.
cyfluthrin + imidacloprid (Leverage)	F-G						F-G	G	G-E	worms (G)	Rotational restrictions & non-target impacts.
deltamethrin (Battalion, Decis)						X					Has been used in efficacy trials in WA state but with very low LEP pressure. Suspected of being G-E on LEP, but currently not enough data to prove.
endosulfan (Thiodan)	F-G	G					F-G	G	X	stink bugs (G)	Short period of efficacy.
esfenvalerate (Asana)	P	E				E		E	G-E		Resistance issues.
ethoprop (Mocap)			F-G	G							Critical for WRW control. Not good on high populations.
flonicamid (Beleaf)	G-E										New. Highly selective.
imidacloprid (Admire Pro, Gaucho)	E	E	P				F-G			beetles (G-E)	
malathion (Cythion)										Grasshoppers (G)	AK problem only.
metam-based products (K-pam, Vapam)			G	G							Contact only.

Efficacy Table for Insect Management in PNW Potatoes, cont.

	green peach aphid	Colorado potato beetle	wireworm	symphylans	spider mites	lepidoptera	beet leafhoppers	Lygus bug	potato tuberworm	other	Comments
methamidophos (Monitor)	E	G				G	F-G	F	G-E	beetles (G), thrips (G)	A very reliable aphicide for GPA. Critical for seed production.
methomyl (Lannate)	F								G-E	various (F-G)	Limited use currently.
novaluron (Rimon)						X			G-E	beetles, aphids (P)	
oxamyl (Vydate)	G	G-F			F-P			F			
permethrin (Pounce, Ambush)		E-G				E		E	X	potato aphid (F), beetles (F)	Not effective for GPA. Resistance issues.
phorate (Thimet)	F-G	G	F							beetles (G)	
phosmet (Imidan)		G							G-E		Resistance issues.
propargite (Comite, Omite)					F				P		
pymetrozine (Fulfill)	G-E								P	aphids (G-E)	Newly registered. Promising for shorter season crop. Unique mode of action. Reduces virus (PLRV) transmission.
spinosad (Success)		G-E				G			G-E	thrips (G), worms	Expensive
spiromesifen (Oberon)					G-E				P		
sulfur (Micro Sulf)					F-P						
thiamethoxam (Cruiser, Platinum)	E	E					F-G				
Pipeline Materials and Possible Biologicals											
bifenazate (Acramite)					F						Tolerance established for potatoes by IR-4. Awaiting registration.
bifenthrin (Capture)			F								
fipronil (Regent)	F		E								An in-furrow insecticide treatment that has proven effective in controlling wireworms and may have some early season control of CPB. Its registration on potatoes is being reviewed by EPA.
metaflumizone (Alverde)		E				G			G		Registration expected in 2007. Supression of potato leafhopper, leafminer (*Lyriomyza* spp. only), psyllids, and flea beetles
spirotetramat (Movento)											To be registered for use on aphids.
Tebupirimfos + cyfluthrin (Aztec)		G	G-E								Registered in corn. Registration on potatoes not currently being pursued by IR-4.
tefluthrin (Force)			G-E							soil insects	Registered in corn. Registration on potatoes not currently being pursued by IR-4.
Biological Insecticides											
azadirachtin (Agroneem, Ecozin, Neemix)										various insects	

Efficacy Table for Insect Management in PNW Potatoes, cont.

	green peach aphid	Colorado potato beetle	wireworm	symphylans	spider mites	lepidoptera	beet leafhoppers	Lygus bug	potato tuberworm	other	Comments
Bacillus thuringiensis spp. *aizawai* (Agree, Ketch, XenTari)						G					
Bacillus thuringiensis spp. *Berliner (BT 320 Sulfur 25 Dust)*										cabbage looper (G)	
Bacillus thuringiensis spp. *tenebrionis* (Novodor)		G									Priced too high.
Bacillus thuringiensis strain EG7841 (Crymax)											Both aizawai and kurstaki toxins.
Beauvaria bassiana (Mycotrol)										various insects	
cryolite (Na aluminofluoride) (Kryocide)		G			G						
jojoba oil (Erase ECO)										whiteflies (F-G)	
neem oil (Trilogy)					F						
potassium salts of fatty acids (M-Pede)										soft-bodied arthropods	
IPM and Cultural Control											
clean/certified seed	X								X		This will ensure low initial virus infection but it will not prevent any insect damage.
control weeds/alternate hosts	X	X					G				
economic thresholds	F	E									
irrigation management									X		
physical examination of leaves	G	G			G						
resistant varieties	G		G								Not commercially available yet.
rotate to non-host crops 3 out of 4 years		E	G								
scout fields	E	E			E						
selective plowing/tillage			F								
transgenic varieties		E									Not used. Lack of market acceptance.

Efficacy rating symbols: E = Excellent (90-100% control), G = Good (80-89% control), F = Fair (70-79% control), P = Poor (<70% control), X = This control is used and is believed to have some efficacy against this pest but is likely not a stand-alone method.

Efficacy Table 1 of 3 for Weed Management in PNW Potatoes

This table is a compilation of information concerning various compounds and practices utilized on weed pests of potato in the PNW states excluding Alaska. Efficacy of various registered and unregistered compounds on general categories of weeds (volunteer grains, broadleaf weeds, and grassy weeds) is shown in this table. The table following this one (Table 2 of 3) indicates efficacy on specific weeds. Table 1 also provides information on the timing of application for products, products' efficacies on emerged weeds, whether or not products are tank mixed, whether regional differences exist within the PNW, and whether resistance concerns are present. IPM practices including cultural control methods are shown. An "X" means this method is utilized and provides a measure of control as part of an overall integrated program. Table 3 of 3 deals with weeds in Alaska potato production.

	volunteer grain	broadleaf weeds	grasses	timing (PP = before potatoes are planted; PRE = before potatoes emerge; POST = after potato emergence)	effective on emerged weeds?	tank mix	regional differences	resistance concerns
Registered Herbicides								
clethodim (Select)	G-E	N	G-E	POST	X	X		X
dimethenamid-p (Outlook)	G	G-E	G	PRE		X	X	
EPTC (Eptam)	F-G	F-G	F-G	PP, PRE, POST		X	X	
flumioxazin (Chateau)	N	F-G	N-F	PRE		X	X	
glyphosate (Roundup and others)	E	E	E	PP, PRE	X	X		X
metolachlor (Stalwart)	P	F	F	PP, PRE, POST		X	X	
metribuzin (Sencor and others)	F-G	G-E	F-G	PP, PRE, POST	X	X		X
paraquat (Gramoxone Max)	E	E	E	PP, PRE	X	X		
pendimethalin (Prowl H_2O, 3.3EC)	P-F	F-G	F	PRE, POST		X	X	
rimsulfuron (Matrix)	G	G-E	G	PRE, POST	X	X	X	X
s-metolachlor (Dual Magnum/Dual II Magnum)	P	F-G	F-G	PP, PRE, POST		X	X	
sethoxydim (Poast Plus)	G-E	N	G-E	POST	X	X		X
trifluralin (Treflan HFP)		F-G	F-G					
Herbicides Not Currently Registered or Available for Use on Potatoes								
ethalfluralin (Sonalan)	P-F	F	F-G	PRE		X		
flufenacet (Define)	F-G	P	F-G	PRE		X		
sulfentrazone (Spartan)	P	G-E	P	PRE		X	X	
IPM and Cultural Control								
adjust herbicide rate based on weed pressure and soil characteristics	X	X	X				X	
choose rotational crops that compete with weeds and/or break up weed life cycle	X	X	X				X	
cultivate for weed control							X	
keep accurate herbicide use and weed infestation records for each field	X	X	X					
promote a healthy, competitive potato crop	X	X	X					
rotate herbicide classes to avoid development of herbicide resistant weed populations							X	
scout fields and identify weed species correctly	X	X	X				X	
time hilling/cultivation operations in conjunction with herbicide applications for more effective control					X		X	

Efficacy rating symbols: E = Excellent (90-100% control); G = Good (80-89% control); F = Fair (70-79% control); P = Poor (<70% control); N = None.

Efficacy Table 2 of 3 for Weed Management in PNW Potatoes

This table, adapted from PNW Weed Management Handbook, is a compilation of information concerning the efficacy of various compounds on potato weed pests in the PNW states excluding Alaska.

	dimethinamid-p (Outlook)*	EPTC (Eptam)	ethafluralin (Sonalan)†	flumioxazin (Chateau)‡	metolachlor (Stalwart)	pendimethalin (Prowl H_2O/3.3EC)	s-metolachlor (Dual Magnum/Dual II Magnum)	sulfentrazone (Spartan)†,§	trifluralin (Treflan HFP)	metribuzin (Sencor, others) **	metribuzin (Sencor, others)**	rimsulfuron (Matrix)**	rimsulfuron (Matrix)**	sethoxydim (Poast Plus)**, ††	clethodim (Select)**, ††	glyphosate (Roundup, others)**	paraquat (Gramoxone Max)	paraquat (Gramoxone Max)‡‡	diquat (Reglone)	endothall (Desicate II)	carfentrazone-ethyl (Aim)	glufosinate-ammonium (Rely)	sulfuric acid	pyraflufen ethyl (ET)
Application Timing§§	**PRE**	**PP, PRE, POST**	**PRE**	**PRE**	**PP, PRE, POST**	**PRE, POST**	**PP, PRE, POST**	**PRE**	**PP, PRE**	**PRE**	**POST**	**PRE**	**POST**	**POS**	**POS**	**PP, PRE**	**PP, PRE**	**VK**	**VK**	**VK**	**VK**	**VK**	**VK**	**VK**
Controls Emerged Weeds										√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Weeds																								
barley, volunteer	F-G	G-F	P-F	N	P-F	P-F	P-F	N	P	F	F-G	G	G	G	G	G	G	G	L	L	L	L	L	L
barnyardgrass	G	G	G	N	P-F	G	G	N	G	F	F-G	G	G	G	G	G	G	G	L	L	L	L	L	L
bindweed, field	L	P	P	L	NE	P	NE	L	P	P	P	L	P	N	N	P-F	F-G	F-G	L	L	L	L	L	L
cocklebur, common	F	P	F	L	NE	N	NE	F	P	F	F	F	F-G	N	N	G	G	G	L	L	L	L	L	L
crabgrass	G	G	G	N	F	G	G	N	G	F	F-G	F	G	G	G	G	G	G	L	L	L	L	L	L
foxtail spp.	G	G	G	N	F-G	G	G	N	G	G	G	G	G	G	G	G	G	G	L	L	L	L	L	L
knotweed, prostrate	P	G	G	P	L	G	L	G	G	G	G	L	L	N	N	G	F-G	F-G	L	L	L	L	L	L
kochia	F	F-P	F-G	P-F	F	F-G	F	G	F-G	G-E	G-E	F-G	F-G	N	N	G	G	G	L	L	L	L	L	L
lambsquarter, common	P-F	G	F-G	P-F	F	G	F	G-E	F-G	G-E	G-E	F	F-G	N	N	G	G	G	L	L	L	L	L	L
mallow, common	L	P	P	L	F	F	F	G	P	G	G	P	P	N	N	F	F-G	F-G	L	L	L	L	L	L
mustard spp.	L	P	P	F	P	NE	P	G	P	G	G	G	G	N	N	G	G	G	L	L	L	L	L	L
nightshade, cutleaf	G	P-G	P-F	F-G	P-F	P-F	P-F	G	P	P	P	N	N	N	N	F	G	G	L	F-G	G	G	G	L
nightshade, hairy	G-E	P-G	P-F	G-E	P-F	P-F	P-F	G-E	P	P-F	P-F	G	G-E	N	N	G	G	G	F-G	F-G	G	G	G	F-G
nutsedge, yellow	F-G	F	P	F	F	P	F-G	F	P	P	P	G	F	N	N	P-F	P-F	P-F	L	L	L	L	L	L
oat, volunteer	F-G	G-F	P-F	N	P	P	P	N	G	F-G	F-G	F-G	G	G	G	G	G	G	L	L	L	L	L	L
oat, wild	F-G	G-F	F	N	P-F	P-F	P-F	N	F	F-G	F-G	F	G	G	G	G	G	G	L	L	L	L	L	L
pigweed spp.	G	G-F	G	P-F	F-G	F-G	G	G	G	G-E	G-E	G	G	N	N	G	G	G	F-G	F	F-G	F-G	G	F
purslane, common	G	G	G	P-F	F-G	G	G	G	G	G	G	F	F	N	N	F-G	F-G	F-G	L	L	L	L	L	L
quackgrass	L	F-G	P	N	NE	NE	P-F	N	P	P-F	F	N	G	F	G	F	P-F	P-F	L	L	L	L	L	L
sandbur, field	G	G	G	N	F-G	L	G	N	G	P	P	L	L	G	G	G	G	G	L	L	L	L	L	L
smartweed spp.	L	P	F-G	P	P	F	P	G	P-F	F	F-G	F	F	N	N	G	G	G	L	L	L	L	L	L
sunflower, wild	P	P	P	P	P	P	P	N	P	F	F	F-G	F-G	N	N	G	G	G	L	L	L	L	L	L
thistle, Canada	L	P	P	L	P	P	P	L	P	F	F	P	F	N	N	F	P-F	P-F	L	L	L	L	L	L
thistle, Russian	P	P	F-G	P-F	P	G	P	G	F-G	G	G	P	P	N	N	G	G	G	L	L	L	L	L	L
wheat, volunteer	F	F-G	P-F	N	P	P-F	P	N	F	P-F	F	G	G	G	G	G	G	G	L	L	L	L	L	L

* Rate dependent on soil texture. † Not currently registered or available for use in potatoes. ‡ Potato vegetation must be covered by 2 inches of soil at application.

§ Crop safety highly dependent on soil pH, texture, and moisture. ** Resistant weed biotypes/populations present in the PNW. †† Only controls grass species. ‡‡ Only for use on potatoes not going into storage.

§§ PP = Before potatoes are planted; PRE = Before potatoes emerge; POST = After potatoes emerge; VK = At vine-kill

Efficacy rating symbols: E = Excellent (90-100% control), G = Good (80-89% control), F = Fair (70-79% control), P = Poor (<70% control), N = None (No control), NE = Not Effective, L = Limited Information

Efficacy Table 3 of 3 for Weed Management in PNW Potatoes: Alaska								
	glyphosate (Roundup)	linuron (Lorox) (24[c])	metribuzin (Sencor and others)	oxyfluorfen (Goal) (registered on cabbage, not on potatoes)	paraquat (Gramoxone Extra)	pendimethalin (Prowl)	rimsulfuron (Matrix)	sethoxydim (Poast Plus)
chickweed	G	E	G		G		E	
fireweed	G				F-G			
hempnettle	N	F-G	F-G*	F	P-F		G*	
lambsquarters	G	E	E*	G	F-G		E*	
perennial sowthistle	G-E	G-E	G-E		F-G		G-E	
pineapple-weed	G	G-E	G	F-G*	F-G		G	
prostrate knotweed	F	P	G	G*	P	G	N	
quackgrass	G-E*	P	P		P		F-G	G
shepherd's purse		G		G	F-G	G		
volunteer grain	G	G	G	E	G		G-E	G-E
wild buckwheat	G	G-E	G-E	G	F-G		F-G	
* Early stages 2 seed leaf or less								
Efficacy rating symbols: E = Excellent (90-100% control), G = Good (80-89% control), F = Fair (70-79% control), P = Poor (<70% control), N = None (No control)								

Toxicity Ratings on Pollinators and Beneficials in Potatoes

AB = Alkalai Bees, **HB** = Honeybees, **LCB** = Leafcutting bees, **BEB** = Big-eyed bugs, **CB** = Carabid beetles (Carabidae family) and rove beetles (Staphylinidae family), **DB** = Damsel bug, **LW** = Lacewings (*Chrysopa* spp.), **LB** = Lady beetles (*Coccinella septempunctata*, *Harmonia axyridis*, *Hippodamia convergens*), **MPB** = Minute pirate bugs (*Orius* spp.), **PBT** = Predatory beetles (*Stethorus* spp.), **PM** = Predatory mites (Acari: Phytoseiidae), **PN** = Predatory nematodes, **PW** = Parasitic wasps (Braconidae, Chalcidae, Ichneumonidae, and Mymaridae families), **S** = Spiders (*Erigone aletris*, *E. blaesa*, and *E. dentosa*), **SF** = Syrphid flies, **TF** = Tachinid flies, and **TSS** = Two-spotted stinkbug.

Rating Scale: E = Excellent survivability (non-toxic), G = Good survivability (slightly toxic), F = Fair survivability (moderately toxic), P = Poor survivability (highly toxic), ND = No data, Blank = Do not know.

Rating Scale (Pollinators only): 0 = No data or experience available, 1 = Do not apply to blooming plants (residual greater than 1 day), 2 = Apply in evening after bees have stopped foraging (residual 4-12 hours), 3 = Apply in late evening until early morning (residual 2-4 hours), 4 = Apply at any time with reasonable safety to bees (residual negligible).

	Pollinators			Beneficials														
	AB	HB	LCB	BEB	CB	DB	LW	LB	MPB	PBT	PM	PN	PW	S	SF	TF	TSS	Comments
Registered Insecticides/Miticides																		
abamectin (Agri-Mek)	2	3	3	P		ND	F	F-P	P	P	P-F	ND	P	ND	G	ND		
acetamiprid (Assail)		G-F		F		F	ND	F	ND		G-F	ND	F	ND	ND	ND		
aldicarb (Temik)				P		P			F-P					E				
bifenazate (Acramite)				G		G	G	G-E	G-E		G-E	ND	G	G	G	G		
bifenthrin (Capture)	1	1	1	F-P		F-P	F-P	F-P	F-P		F-P		P	P	P	P		
carbaryl (Sevin)	1	1	1	F-G		F-G	F-G	P	F-G		P	ND	F	F	F	F		
carbaryl (Sevin) bait		4						G										
carbofuran (Furadan)	1	1	1	F-P		F-P	F-P	F-P	F-P					F-P				
cyfluthrin (Baythroid)																		
cryolite bait		E																

Toxicity Ratings on Pollinators and Beneficials in Potatoes, cont.

	Pollinators			Beneficials														
	AB	HB	LCB	BEB	CB	DB	LW	LB	MPB	PBT	PM	PN	PW	S	SF	TF	TSS	Comments
endosulfan (Endosulfan)	3	1	2	F-P	F								F	P-F	F	F		
esfenvalerate (Asana)		E		F		P-F	F	P	P		P	ND	P	P	P	P		
ethoprop (Mocap) (insecticide, nematicide)		G		G	G	G	G	G	G		G	P?	G	G	G	G		
flonicamid (Beleaf)		G		G		G	G	G	G		G	ND	G	G	G	G		
imidacloprid, soil-applied (AdmirePro)		F		F-G		F-G	F-G			P		ND	G	G-E	G	G		Not toxic to foliage-borne beneficials
imidacloprid, foliar (Provado)		F		F		F	F	F-P	F-P	P	F-P	ND	F	F	F	F	F	
methamidophos (Monitor)																		Broad toxicity, moderately toxic
methomyl (Lannate)	1	1	1	F-P		F-P	P	P	P		P	P	P	F	P	P		
novaluron (Rimon)											E		E					
oxamyl (Vydate)		P		P		P	P	P	P		P	P	P	P	P	P		
permethrin (Ambush, Pounce)	1	1	1	F-P		F-P	F-P	F-P	F-P		F	ND	F	F	F	F		
phorate (Phorate, Thimet)				F		G-F			G-F					F				
phosmet (Imidan)	1	1	2				G	P			E							
propargite (Comite)	4	4	4	G		G	G	E	F	P		ND	ND	ND	ND	ND	ND	
pymetrozine (Fulfill)	3	3	3	G		G	G	G	G		G							
spinosad (Entrust, SpinTor, Success, Tracer)		F		F		F	F-G	F	F		F	ND	F	F	F	F		
spiromesifen (Oberon)																		

Toxicity Ratings on Pollinators and Beneficials in Potatoes, cont.

	Pollinators			Beneficials														
	AB	**HB**	**LCB**	**BEB**	**CB**	**DB**	**LW**	**LB**	**MPB**	**PBT**	**PM**	**PN**	**PW**	**S**	**SF**	**TF**	**TSS**	**Comments**
sulfur (Sulfur)	4	4	4	G		G	F-G	F-G				ND	F	ND	F	F		
tebupirimphos + cyfluthrin (Aztec)																		
tefluthrin (Force)																		
thiacloprid (Calypso, Alanto)																		
thiamethoxam, foliar (Actara)		F		F-G		F-G	F-G	F-G	F-G		F-G	F-G	F-G	F-G	F-G	F-G		
thiamethoxam, soil-applied (Platinum)		F-G		G		G	G	G	G		G		G	G	G			Low probability of harm to beneficials
Seed Treatments																		
imidacloprid (AdmirePro, Gaucho)		E		E	E	E	E	E	E		E		E	E	E	E		
thiamethoxam (Cruiser)		E		E	E	E	E	E	E		E		E	E	E	E		
Biological Insecticides																		
azadirachtin (Azatin, Aza-Direct)		G		G-E		G-E	G-E	G-E	G-E		G-E	ND	G-E	G-E	G-E	E		
Bacillus thuringiensis	4	4	4	E		E	E	E	E		E	E	E	E	E	E		
Bacillus thurigiensis spp. *kurstaki* (DiPel Esy, others)				E		E			E					E				
Other Low-Risk Insecticides																		
soaps (M-Pede)		G		G	G	G	G	G	G		G	G	G	G	G	G	G	No data but general mode of action may prove toxic to leaf-borne beneficials

Toxicity Ratings on Pollinators and Beneficials in Potatoes, cont.

	Pollinators			Beneficials														
	AB	**HB**	**LCB**	**BEB**	**CB**	**DB**	**LW**	**LB**	**MPB**	**PBT**	**PM**	**PN**	**PW**	**S**	**SF**	**TF**	**TSS**	**Comments**
Fumigants																		
1,3-dichloropropene (Telone II)												P						Not toxic to foliage-borne beneficials
chloropicrin + 1,3-dichloropropene (Telone C-17)												P						Not toxic to foliage-borne beneficials
metam-based products (Vapam, K-pam)												P						Not toxic to foliage-borne beneficials
Cultural/Non-Chemical Controls																		
Adjacent area management													P	P	P	P		May be hazardous if habitat removed
Cover crops																		Provide good habitat, shelter, and alternative prey for the beneficials
Isothiocyanate cover crops							E	E	E	E	E		E	E				
Crop rotation																		Variable ecological impacts on polyphagous natural enemies
Enhancing habitat for beneficials																		Beneficial, habitat, shelter, and alternative prey
Hand hoeing				P		P	P	P	P		P		P	E	P	P		Neutral
Mowing																		Short term disruption to foliage dwellers
Mulching																		Beneficial, habitat, shelter, and alternative prey
Raised beds																		May be beneficial to soil dwellers
Sanitation																		May be hazardous if habitat removed

Toxicity Ratings on Pollinators and Beneficials in Potatoes, cont.

	Pollinators			Beneficials														
	AB	**HB**	**LCB**	**BEB**	**CB**	**DB**	**LW**	**LB**	**MPB**	**PBT**	**PM**	**PN**	**PW**	**S**	**SF**	**TF**	**TSS**	**Comments**
Tillage																		Short term disruption to soil dwellers
Weed control around field borders																		May impact habitat/alternative prey for some species
Weed management																		May impact habitat/alternative prey for some species