OREGON STATE UNIVERSITY EXTENSION SERVICE

Integrated Pest Management Strategic Plan for Potatoes

in Oregon, Washington and Idaho

Summary of a workshop held on Feb. 22, 2019
Portland, Oregon

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Table of contents

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Process for this integrated pest management strategic plan

In a proactive effort to identify pest management priorities and lay a foundation for future strategies and increased use of integrated pest management (IPM) in potato production, experts from the potato industry in Oregon, Washington and Idaho formed a work group and assembled this plan. This group, comprised of growers, commodity-group representatives, pest control advisers, university research and Extension representatives, and other technical experts, met for a day in February 2019 in Portland, Oregon, where they discussed and reached consensus about this plan. This document outlines major pests, current management practices, critical needs, activity timetables, and efficacy ratings of various management tools for specific pests in potato production. The result is a strategic plan that addresses many IPM and pest-specific critical needs for the Pacific Northwest potato industry. Note that seed-potatoes are not covered by this document.

A list of top-priority critical needs was created based on a group voting process at the work group meeting. A list of broader IPM needs was also compiled, based on identified needs related to specific topics. Crop-stage-specific critical needs are also included, listed, and discussed throughout this publication.

This strategic plan begins with an overview of potato production. The overview is followed by discussion of critical production aspects of this crop, including regional differences, export issues and the basics of IPM in potato production in the Pacific Northwest. Each pest is described briefly, with links provided for more information about the pest's biology and life cycle. Within each major pest grouping (insects, diseases and weeds), **individual pests are presented in alphabetical order, not in order of importance**. The remainder of the document is an analysis of management practices and challenges organized by crop life-stage in an effort to assist the reader in understanding whole-season management practices and constraints. Current management practices are presented using a Prevention, Avoidance, Monitoring, and Suppression (PAMS) framework to place practices within a simple IPM classification and to demonstrate areas where additional tools or practices may be needed. For more information, see Appendix G, "Using PAMS Terminology" (page 85).

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

Work group members

In attendance

Nick Benavides, Castle Rock Farms

Travis Blacker, Idaho Potato Commission

Matthew Blua, Washington State Potato Commission

Sherilyn Bye, Wilbur-Ellis Co.

Brian Charlton, Oregon State University

Greg Jackson, crop consultant, Two Rivers Terminal

Andrew Jensen, Washington, Idaho, and Oregon potato commissions

Nate McBride, Mart Produce

Jeff Miller, Miller Research

Grant Morris, grower

Bink Ramos, Nutrien Ag Solutions

Brett Reynolds, grower/consultant

Jennifer Riebe, crop consultant

Silvia Rondon, Oregon State University

Alan Schreiber, independent researcher

Tim Waters, Washington State University Extension

Carrie Wohleb, Washington State University Extension

Others in attendance

Paul Jepson, Integrated Plant Protection Center, Oregon State University

Katie Murray, Integrated Plant Protection Center, Oregon State University

Isaac Sandlin, Integrated Plant Protection Center, Oregon State University

Contributing work group members not in attendance at workshop

Kenneth Frost, Oregon State University

Pam Hutchinson, University of Idaho

Nora Olsen, University of Idaho

Mike Thornton, University of Idaho

Review of 2006 summary of the most critical needs in Pacific Northwest potato pest management

A pest management strategic plan (PMSP) was developed for potato in 2002 and updated in 2006. The following needs were identified by the 2006 work group as "most critical." An update on current progress, in *italics*.

Research

- Develop comprehensive pest prediction models, reliable sampling methods and accurate action threshold levels.
  - ❑ *Progress has been made in these areas (late blight hotlines, mapping and weekly monitoring programs have been developed and deployed), but needs remain.*
- Develop pest management strategies that lower inputs or costs for growers while maintaining the sustainability of potato production.
  - ❑ *This remains an important need for the industry.*
- Investigate the management and impacts of green manures in potato cropping systems.
  - ❑ *Research has been conducted on the use of biofumigant mustards. Soil health efforts are ongoing, but more research is still needed.*
- Investigate soil microbes and their benefits to pest management; determine what effects fumigants and biological amendments have on the soil microbial community.
  - ❑ *Soil health research is ongoing, including the impacts of fumigants and biological amendments, but this is an area where more research is still needed.*
- Research alternatives to chlorpropham for sprout inhibition in stored potatoes.
  - ❑ *Several alternatives are now registered; additional cost-effective alternatives are still needed.*
- Investigate the interaction of pest management strategies and their effects on pest control and potato crop safety.
  - ❑ *Understanding impacts of management practices is an ongoing need.*
- Develop areawide management plans for the management of the *Potato virus Y* complex.
  - ❑ *It is questioned whether areawide management is the best solution to this virus, but management solutions are still needed.*
- Investigate the biology and interaction of potato pests, including new emerging pests.
  - ❑ *Research has been conducted on the biology of a number of potato pests, including potato psyllid, tuberworm, beet leafhopper, cyst nematode, lygus, Verticillium, etc. However, more pest biology research is needed.*
- Research powdery scab management.
  - ❑ *Research on effective management for powdery scab is ongoing. This is a top disease concern for non-russet fresh market growers.*

- Determine pesticide impacts on beneficial and other nontarget organisms.
  - *Research has been conducted on the impacts of pyrethroids in causing secondary pest outbreaks (mites, aphids and thrips). This research needs more dissemination. Since 2006, more target-specific chemistries have been introduced, which have fewer negative impacts to beneficials. However, more research is needed on successful implementation.*
- Develop pesticides with different or new modes of action to guard against the development of resistance.
  - *This continues to be an issue, as the pressure to reduce overall pesticide use can have negative impacts to resistance management if not managed carefully. Herbicide resistance management is a particular issue, with no new herbicide modes of action in recent years.*
- Research the management of potato tuberworm and potato cyst nematode.
  - *Tuberworm is still present but no longer considered a major pest problem. Control is better understood. Much research has been done on eradication and management for cyst nematode.*
- Research the effect of different agronomic practices on pests and their management.
  - *Understanding impacts of various management practices is an ongoing need.*

Regulatory

- Work with the Environmental Protection Agency in addressing Food Quality Protection Act issues to provide realistic and commonsense risk assessment data in order to avoid the loss or cancellation of pesticides.
  - *Although work has been conducted in this area, this remains an important regulatory need.*
- Allow resistance-management and crop-rotation practices as a justification for Section 18 labels.
  - *Section 18 process is not currently used as much as it has been in previous years. Resistance-management justification can be used once resistance is shown to be a problem, but resistance prevention cannot be used as justification currently in the Section 18 process.*
- Maintain the tolerance for chlorpropham until a viable economic alternative is available.
  - *Chlorpropham registration still exists, but with decreased tolerances. Alternatives have been identified, but they are not as cost-effective.*
- Regulate and enforce strict seed certification and phytosanitary standards across state and national borders to prevent pests that we do not already have.
  - *This is an ongoing issue that requires continued attention.*
- Encourage Natural Resources Conservation Service to provide cost-share money for additional IPM practices.
  - *NRCS has programs for best management practices, but these do not always align with IPM specifically. Cost-share ideas that work for growers and offer incentives for IPM advancements are still needed.*

- Improve communication with NRCS to develop realistic conditions for cost sharing.
  - ❑ *Improving the cost-share program continues to be a need.*
- Provide tuberworm traps and monitoring for large-scale studies.
  - ❑ *Tuberworm is still present but no longer considered a major pest problem, and control is better understood. This is no longer considered a need.*
- Preserve organophosphate and carbamate chemistries until suitable alternatives for the same pest spectrum are developed.
  - ❑ *Many of these products have been phased out. While alternatives exist, the remaining organophosphate and carbamate chemistries are important as additional tools for use as-needed.*
- Implement State National Harmonization Program for seed potatoes.
  - ❑ *This is an ongoing need with work still in process.*

Education

- Provide accessible, web-based pest management information, including an online clearinghouse for research data.
  - ❑ *A number of websites have been developed that provide web-based pest management information, including the Northwest Potato Research Consortium website and several pest-monitoring websites. However, compiling existing research and making it accessible to a wide industry audience remains an ongoing need.*
- Educate growers about the use of green manures for pest management, including the different types of green manures and which varieties target which pests.
  - ❑ *This is currently not considered a high priority.*
- Educate the industry and the public about science-based information. (Why are nonconventional crop products so successful?)
  - ❑ *This is an ongoing need.*
- Educate growers and consultants about interdisciplinary pest management.
  - ❑ *Workshops are constantly developed on demand.*
- Increase interdisciplinary pesticide resistance management education for growers, crop advisors, and regulators (such as Insecticide and Fungicide Resistance Action Committees).
  - ❑ *Education on pesticide resistance management remains an ongoing need.*
- Educate NRCS and growers about how to utilize NRCS money (from all programs, including Conservation Stewardship Program and Environmental Quality Incentives Program) for pest management.
  - ❑ *More work is needed with NRCS to make programs more accessible and useful to growers.*
- Educate growers about the proper use of pesticides (including appropriate application timing and proper pest identification before application).
  - ❑ *This is an ongoing need.*

2019 top-priority critical needs

The following critical needs were voted as the "top-priority" needs by the work group members present at the February 2019 meeting. Crop-stage-specific aspects of these needs, as well as additional needs, are listed and discussed throughout the body of the document. Note that the order of appearance within these lists does not reflect an order of importance.

Research topics

- Develop effective alternatives to fumigation
- Assess fumigant impacts on beneficials and consequences for early season pest suppression
- Establish action thresholds for potato insect pests
- Evaluate efficacy of crop health biostimulants
- Determine the value of soil health assessments: which ones to use, how to interpret results, how results translate to production
- Refine decision support tools for potato diseases, including mapping and forecasting

Regulatory actions

- Maintain currently registered management tools for potato
- Consolidate various auditing requirements to reduce the auditing and paperwork burden on growers
- Utilize the IR-4 process (Interregional Research Project No. 4) to register products with new modes of action for use in potato to combat pesticide resistance
- Clarify the importance of aerial application of certain pesticides due to limitations on entering potato fields after row closure.
- Harmonize pesticide label formats so that categories of information are found in the same place on every pesticide label.
- Improve the MRL system: address MRL issues prior to registration; standardize MRLs across all countries

Education

- Utilize demonstration trials, success stories, and other promotional and experiential activities to accelerate adoption of new principles and practices related to IPM and pesticide selection.
- Educate growers and consultants on ways to optimize pesticide selection and compare products based on label language.
- Educate growers and consultants on the use of package mixes (such as pyrethroids + neonicotinoids) and impacts to resistance management.
- Compile and disseminate existing and relevant potato research and information
- Increase public outreach on regulatory issues

Potato production overview

The United States is among the top 10 potato producers worldwide, and all 50 states cultivate potatoes. However, based on recent statistics from the National Agricultural Statistics Service, Oregon, Washington, and Idaho produce over 60% of all U.S. grown potatoes. Idaho is consistently ranked first in potato production and acreage at 31.6% of total U.S. production, followed by Washington, with 23.9% of total U.S. production. Oregon ranks fourth in total U.S. production after Wisconsin with approximately 6%. Other top potato-producing states are California, Colorado, Minnesota, Michigan, Maine and North Dakota.

Idaho has approximately 315,000 planted acres, at a value of $960 million to the state. The majority of potato production is adjacent to the Snake River Plain in southern Idaho, where water is available for irrigation. The majority of acres in Idaho are sprinkler irrigated by center pivots, but set-and-move lines and solid-set irrigation are also used. Major production regions in Idaho include, in order of production volume: southeastern Idaho, eastern Idaho, the Magic Valley and the Treasure Valley.

Washington has approximately 165,000 planted potato acres, at a value of about $700 million. 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. Center-pivot irrigation is used on more than 90% of the potatoes grown in the Columbia Basin; furrow and drip irrigation are used on the remainder.

A small portion of Washington's potato crop, mainly fresh market potatoes, is produced on the west side of the Cascade Mountains in the Skagit Valley and Whatcom County. Most potato acres west of the Cascades are sprinkler-irrigated on an as-needed basis to supplement rainfall. The amount of irrigation needed in that region has increased substantially as climate change has led to warmer and drier summers.

Oregon has approximately 46,000 planted acres, at a value of $210 million to the state. 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. About 95% of Oregon's potato acreage is under center pivot irrigation systems. The remaining acres are irrigated by wheel line, furrow, lateral move and solid set systems.

Across these three states, there are at least five distinct growing regions that we refer to in this document, including:

- Columbia Basin of Washington and Oregon
- Treasure Valley of Oregon and Idaho
- Magic Valley of Idaho
- West Cascades of Oregon and Washington, and
- Eastern Idaho and the Klamath Basin (not a contiguous region, but climatically similar areas)

In the Pacific Northwest, potatoes are planted in the spring and harvested in late summer and fall. Potatoes are produced as annual plants that grow from previously propagated tubers referred to as seed potatoes. These seed pieces, which are either left whole or cut to approximately 2 ounces in size, are treated with insecticides or fungicides or both before planting. Good-quality seed potatoes are critical to a successful crop.

Potatoes emerge between two and four weeks after planting. About 30 days following emergence, the potato vines grow together to form a solid canopy. After this stage, most pesticide and fertilizer applications are made by air or chemigation to avoid damaging the foliage. The ability to successfully manage pests during this timeframe is impacted by the efficacy and regulatory requirements of some applied materials.

Most potatoes are grown under either fresh market or processing contracts that dictate which cultivars are produced. The Northwest Potato Variety Development Program, composed of research and Extension staff from the land grant universities and United States Department of Agriculture Agricultural Research Service, has been working since the 1970s to develop new potato cultivars with a wide range of disease resistance. The complex tetraploid genetics and clonal propagation of potato make this process relatively slow and incremental, but substantial progress has been made, especially with respect to new cultivars that better tolerate soilborne diseases such as *Verticillium* wilt. Promising germplasm will eventually provide new cultivars with resistance to viruses, nematodes, and various fungi and fungus-like diseases. Adoption of new cultivars by the industry is usually slow due to strict end-user requirements (quick-service restaurants, grocery chains, etc.) for shape, starch content, color, skin texture and culinary qualities.

Potatoes are harvested with tractor-driven machines (or specialized self-propelled harvesters) that dig multiple rows of crop on each pass. In much of the Northwest, these harvesters load potatoes directly into trucks that drive alongside. In some parts of the Northwest, the harvester places the potatoes on the ground in an adjoining row to form a "windrow," accumulating potatoes from two passes of the harvester into a single windrow. The potatoes are then lifted into trucks with another pass of equipment.

Depending on conditions of the crop and soil, such as the prevalence of rot, rocks or large organic debris, some crops go through a process called transloading. This is when potatoes are trucked from the harvester to a nearby vacant lot or field edge to be unloaded from the field trucks onto additional sorting conveyors before being loaded into larger, full-size semi-truck trailers for transport to processing factories, table stock packing facilities or storage facilities.

Most Northwest potatoes are stored one to 10 months before marketing. Storage areas are sanitized, and potatoes are loaded into storage buildings whose holding capacity ranges from 3 million pounds (30,000 100-pound bags, also referred to as cwt) to 25 million pounds (250,000 cwt). Potatoes are piled to heights of 12 to 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% or higher). Storage temperature is controlled using fresh air distributed via ducts or tunnels beneath the potatoes. Sprout-inhibiting chemical treatments are also distributed through these channels. Potatoes are typically cured for two to three weeks at 50°F to 55°F for proper wound healing to occur. Final holding temperatures depend upon the cultivar and final use of the potatoes. Seed potatoes are typically stored at 38°F, fresh potatoes at 40–45°F, and processing potatoes at 45–50°F.

Market destinations for Northwest potato crops are important in terms of production practices and pest management needs and approaches. The top market classes, in order of relative size of market are: processing for frozen French fries, fresh market or "table stock," potatoes, processing for dehydrated products and starch, processing for chips and seed potato.

Integrated pest management overview in potato production

Potato is affected by many diseases, insects, nematodes, weeds and vector-transmitted pathogens. The majority of potato fields in the Northwest will have detectable populations of most of the possible potato pests every year, presenting a complicated pest management situation for growers.

Early season plant growth from seed tubers is vigorous, but potatoes become more susceptible to diseases as the plants mature. Growers are challenged to achieve the highest yield and quality before the crop is overcome by diseases, insects, weeds and natural senescence. Pest management can be more difficult and more intense in warmer growing regions, such as the Columbia Basin and the Treasure Valley. Milder winters allow greater overwintering of pests, and a longer growing season allows more time for diseases and pests to impact the crop. However, shorter growing seasons, such as in eastern Idaho, can also be a challenge for pest management.

The Northwest's strong potato-breeding and variety-development program has brought new varieties that are less susceptible to diseases such as Verticillium, late blight and viruses. Genetics for stronger resistance to several other pests are well understood, but cultivars with acceptable production, culinary and processing characteristics are not yet available.

Transgenic pest-resistant cultivars were briefly released in the late 1990s but were soon withdrawn from the market. Although some genetically engineered pest-resistant cultivars are under development or in limited markets, this type of technology is not widely available to growers. Consumer resistance to GMO potato in foreign and domestic marketplaces may prevent widespread adoption, even if such cultivars were released.

During the 20th century, effective management strategies emerged as researchers learned about the biology of potato pests. Advances in agronomics and the availability of effective pesticides continuously increased yields. Although potato is not a major crop, it is large enough to attract the attention of pesticide registrants, giving growers access to many pesticides that effectively control most pests.

Successful management combines cultural practices—such as long crop rotations, careful timing of planting and innovative cultivation techniques—with carefully chosen and timed pesticide treatments. These treatments range from preseason fumigation to seed treatment, planting-time herbicides, fungicides, insecticides and maintenance treatments throughout the season to maximize foliar lifespan.

Since 1990, however, Northwest potato production has been afflicted by several new pests, changes in pest biology, development of pesticide resistance, and the loss of effective and relied-upon pesticides. These factors have caused major losses, disrupted pest-management practices, and led to emergence of secondary pests. Some key examples:

- During the 1980s, a major threat to crop quality was tuber net necrosis caused by potato leaf roll virus (transmitted by aphids. This was kept at bay by a combination of the soil-applied insecticide aldicarb and the foliar insecticide methamidophos. The phase-out of both insecticides during the 1990s and early 2000s led to a period of intense uncertainty and mixed success at PLRV control. Since then, PLRV control has been achieved by improving seed testing and certification requirements and using at-planting and seed treatments of neonicotinoid insecticides.

- In the mid-1990s, the late blight pathogen began a series of changes in terms of genetic types and resistance to fungicides that moved it from an occasional minor pest to an annual threat with economic losses.
- An outbreak of purple top disease occurred in the Columbia Basin in 2002, caused by the beet leafhopper-transmitted virescence agent phytoplasma. Research determined the pathogen, vector and effective management strategies. Early season foliar treatments with pyrethroid insecticides controlled the beet leafhopper. However, pyrethroids predispose fields to outbreaks of aphids, spider mites and thrips, which have subsequently become common pests that must be treated with midseason foliar pesticides.
- A similar disruption and intensification of insecticide use occurred with the arrival in 2011 of zebra chip disease, caused by the *Candidatus Liberibacter* pathogen, and transmitted by the potato psyllid.
- During the 2000s, potato virus Y became a greater threat due to the emergence of recombinant strains that were harder to control in seed production. These strains cause defects or internal damage in harvested tubers. This led to ongoing intensification of aphid and PVY management efforts in seed potato production, and yield and quality losses in commercial potato afflicted by poor-quality seed.
- Growers have relied on many of the same herbicides since the 1980s, with no new modes of action introduced. These products have been effective and relatively easy to use. However, herbicide-resistant weed populations, including acetolactate synthase inhibitor resistant kochia and Russian thistle, and metribuzin-resistant redroot pigweed and common lambsquarter, have begun to appear in many areas of the Northwest. No herbicides have been developed directly for use in potatoes. As a result, growers rely on crop protection companies to research herbicides from other crops and label appropriately for use in potatoes, as well as IR-4 projects, and Section 18 and 24C labeling. More surveying, screening and research is needed to understand and combat herbicide resistance.
- Two vector-borne viruses that can cause tuber damage have recently attracted much attention and concern: Tobacco rattle virus, which is transmitted by the stubby root nematode, and Potato mop top virus, which is transmitted by the powdery scab pathogen *Spongospora subterranea*. These viruses seem to be spreading and becoming more important, and research is underway to prevent long-term losses and increased management costs.
- Soil fumigants control a variety of soilborne pathogens and nematodes. Fumigants have become more heavily regulated, and many uses have been restricted or eliminated in recent years, leaving growers few options for control of diseases such as *Verticillium* and nematodes such as Columbia root-knot.
- In the last five years, Lygus, thrips and mites have arisen as potential emerging pests.

Monitoring is conducted for certain insects, nematodes and pathogens, including soil testing for *Verticillium* and nematodes; trapping for beet leafhopper, tuberworm, potato psyllid and aphid; and foliar monitoring for diseases like late blight, early blight and white mold, and insects like the Colorado potato beetle, aphids, loopers and cutworms, Lygus and stink bugs. This kind of monitoring is common, but monitoring methods are not standardized across the industry, and there are almost no science-based action thresholds for any of these pests. Those that do exist are controversial and rarely used. Growers and their consultants monitor to learn the pest status of their fields but use that information in ways that suit their production programs and acceptable level of personal risk-aversion.

The Northwest has avoided insecticide resistance in Colorado potato beetle, which threatens potato production across much of eastern North America, where the beetle quickly develops resistance to every new insecticide class. Disruptive new pests like beet leafhopper and potato psyllid may lead to insecticide resistance in the beetle as growers intensify insecticide use.

Potato is afflicted by many pests every year in every field. These pests require action to prevent losses. Some standard cultural practices are important in insect, disease and weed management, but pesticides remain the most relied-upon management tool. The industry has struggled to manage new and different pests and faces losses due to pesticide resistance. Industry resilience will benefit from additional IPM tools, such as research-based monitoring methods and action thresholds, better understanding of biological control organisms, their preservation and the services they provide, and the development, adoption and careful use of new pest-resistant cultivars.

Mazimum residue levels and export issues

Idaho, Oregon and Washington produce almost 65 percent of the country's potatoes. More than 60% of that crop is exported (mostly from Oregon and Washington) in such diverse forms as fresh table stock, fresh for processing in the destination country, frozen French fries and dehydrated products. Export markets include most of the world but are concentrated in the Americas and Asia. The three states exported over $1.1 billion in potato products in 2018, according to the Washington State Potato Commission.

Potato exporters and growers must meet international pesticide regulations for crop protection chemicals. The list of available chemicals and corresponding country-specific maximum residue levels change regularly. Difficulties arise when a maximum residue level exists in the United States but not for the importing country, or when an importer's maximum residue level is lower than what is allowed in the U.S. These inconsistencies affect the pest-management options available for growers wishing to export their crop and processors exporting their manufactured potato products. These differences increase the risk of product being rejected because of excessive pesticide residue. It may also mean that a grower must use a less-than-optimal material in order to meet export requirements. For shippers or processors, this also means that there is less flexibility for shipping, with fewer grower lots eligible for certain restrictive export markets. These factors result in the compilation of "do-not-use" lists by some processors—lists of pesticides or active ingredients that growers are prohibited from using on contracted acres.

Often, newer pesticide products are not registered for use in certain export markets because local growers do not need a specific product, the market is too small to justify registration costs or a registration is pending but not yet posted. These delays in maximum residue level adoption in trading partner countries delay the adoption of effective new products by U.S. growers. Some of these new products have exceptional fits in IPM programs, such as being target-specific with little impact to biocontrol organisms. Maximum residue level-related use restrictions can also interfere with resistance management programs in the U.S. by forcing growers to rely on longstanding effective products with inadequate pesticide rotation.

Standardization of international maximum residue levels is an important issue for potato growers in the Pacific Northwest and critical to the maintenance and expansion of export markets. Further, a program to evaluate pesticide residues based on usual grower applications could help determine which products can safely be used, and when and how they should be used in order to meet export maximum residue levels.

Pollinator protection in potato production

Pollination is not required for potato production, but since the harvested crop consists of tubers grown underground, other aspects of potato production necessitate consideration of potential impacts to pollinators. Neonicotinoids are generally used as seed-potato treatments or as side-dressings early in crop phenology. By the time potatoes bloom, these systemic neonicotinoid insecticide residues have declined in the plants, and are at relatively low levels. However, midseason insects (e.g. loopers, Lygus) can be damaging, and often require (nonneonicotinoid) insecticide applications during potato bloom periods.

Potato varieties in the Pacific Northwest usually produce flowers during a short discrete period near the middle of the growing season. These flowers do not produce nectar, reducing their attractiveness to many pollinators like honeybees, and not all bees can harvest the pollen. Research specific to the Northwest is lacking regarding the extent of pollinators present during potato bloom periods, and the semi-desert irrigated agroecosystems of most of the Northwest are different from the areas where published studies have been conducted (e.g., Michigan). Research is warranted to document the type and extent of pollinator presence in potato fields of the Northwest, and to develop guidelines for pollinator best practices, including insecticide avoidance during periods of high pollinator activity, and selection of materials with low risk to pollinators if use is necessary during bloom.

IPM critical needs

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

Decision and knowledge support

- Develop action thresholds for key potato pests, including insects, diseases and weeds.
- Incentivize growers to scout their fields and base treatments on developed action thresholds.
- Effectively demonstrate the efficacy of IPM practices on field-scale levels.
- Develop IPM trainings for farm workers, including lower-level managers.
- Improve imaging technologies and integrate into pest management practices.
- Develop training materials for new consultants on resistance management and IPM approaches.
- Improve the current potato pest-monitoring systems and protocols.
- Establish specific IPM guidelines for potato pests.
- Develop pesticide-selection tools that aid in making comparisons between pesticides.
- Educate and inform growers regularly about threshold-based monitoring approaches.
- Expand outreach tools to deliver pest-management information (web, phone, text alerts, etc.).
- Use decision aid systems from other crops (for example, tree fruit) as a model for potatoes.
- Train more IPM specialists.
- Develop monitoring tools linked to treatment thresholds.

Alternatives to agrochemicals

- Increase understanding of and acceptance for GMOs in the marketplace.
- Educate pest managers on use and benefits, including economics, of maintaining the natural enemy complex.
- Develop pest population growth models to allow for more nontreatment decisions.
- Quantify the impacts of biocontrol.
- Increase the use of trap crops and reduce pest overwintering habitats.
- Increase reliance on independent crop consultants.
- Perform efficacy trials and economic assessment for potential biologically based products.
- Use arthropods and nematodes as bioindicators of soil health and quality.
- Increase research on the biology of natural enemies in the field.

- Demonstrate pest suppression and other benefits of biofumigants (mustard, radish).

Human health and worker protection

- Research and develop ways to treat seed with reduced dust release.
- Develop more worker safety trainings in Spanish.
- Offer Spanish label translations for pesticides.

Soil health

- Determine physical and biological variables that impact soil health.
- Research the impacts of specific crop rotations on soil ecology and identify best rotations for improved soil health.
- Measure the relationship between soil variables and potato yield and quality.
- Research the use of composts for adding nutrients (P, K, Ca, Mg), increasing fertility and enhancing soil-microbes.
- Encourage landowners to commit to long-term soil-building activities.
- Evaluate the efficacy of biostimulants and microbial "soil health" boosters.
- Develop alternatives to fumigants.
- Develop target-specific pesticides for managing nematodes and other soil pests.
- Understand soil-microbiome composition and ecology.

Water quality

- Educate pesticide applicators on best practices for reducing nontarget drift.
- Educate growers about pesticides with lower risks to water quality.
- Educate and train irrigation managers on factors that influence runoff.
- Keep abreast of water-testing requirements and changes for sustainability and food safety audits.

List of major potato pests

(listed alphabetically)

Insects and other arthropods

Aphid (*Myzus persicae*, *Macrosiphum euphorbiae*)

Beet leafhopper (*Circullifer tenellus*)

Caterpillars: cutworm (*Xestra c-nigrum*); armyworm (*Mamestra configurata*); alfalfa looper (*Autographa californica*); cabbage looper (*Trichoplusia ni*)

Colorado potato beetle (*Leptinotarsa decemlineata*)

Grey field slug (*Deroceras reticulatum*)

Psyllid (*Bactericera cockerelli*)

Thrips: onion thrips (*Thrips tabaci*); Western flower thrips (*Frankliniella occidentalis*)

Potato tuberworm (*Phthorimaea operculella*)

Twospotted spider mite (*Tetranychus urticae*)

Wireworm (*Limonius* spp. and *Agriotes* spp.)

Occasional insect pests:

Blister beetle (*Epicauta* spp.)

Field cricket (*Acheta assimilis*)

Seed corn maggot (*Delia platura*)

Spotted winged grasshopper (*Orphulella pelidna*)

Stink bug (several species from the *Pentatomidae* family)

Diseases and nematodes

Black dot (*Colletotrichum coccodes*)

Gray mold (*Botrytis cinerea*)

Common scab (*Streptomyces* scabies)

Early blight (*Alternaria solani*)

Brown spot (*Alternaria alternata*)

Fusarium dry rot (Several *Fusarium* spp., including *F. sambucinum, F. solani* var. *coeruleum* and *F. avenaceum*)

Late blight (*Phytophthora infestans*)

Nematodes: Root knot (*Meloidogyne hapla, M. chitwoodi*), root lesion (*Pratylenchus neglectus*), stubby root (*Paratrichodorus* spp. and *Trichodorus* spp.) (Tobacco rattle virus/corky ringspot vector), pale cyst (*Globodera pallida*) (isolated issue in Idaho)

Periderm disorder syndrome (formerly pink eye)

Pink rot (*Phytophthora erythroseptica*)

Powdery scab (*Spongospora* subterranean)

Pythium leak (*Pythium* spp.)

Rhizoctonia canker (*Rhizoctonia solani*)

Black scurf (*Rhizoctonia solani*)

Ring rot (*Clavibacter michiganensis subsp. Sepedonicus*)

Bacterial soft rot including tuber rot, blackleg, aerial stem rot and lenticel rot (*Pectobacterium* spp. and *Dickeya* spp.)

Silver scurf (*Helminthosporium solani*)

Verticillium wilt (potato early dying) (*Verticillium dahliae*)

White mold (*Sclerotinia* Stem Rot) (*Sclerotinia sclerotiorum*)

Occasional diseases:

Powdery mildew (*Golovinomyces orontii*)

Viruses and insect-transmitted bacteria

Potato virus Y (PVY)(Genus *Potyvirus)*(aphid vectored)

Potato leafroll virus (PLRV)(Genus *Polerovirus*)(aphid vectored)

Potato mop-top virus (Genus *Pomovirus*) slime mold vectored

Purple top, Aster Yellows, Witches'-broom (*Candidatus Phytoplasma* spp.) (leafhopper vectored)

Tobacco Rattle Virus (Genus *Tobavirus*) (nematode vectored)

Zebra chip (*Candidatus Liberibacter solanacearum*) (psyllid vectored)

Weeds

Barley (*Hordeum vulgare*) (volunteer)

Barnyardgrass (*Echinochloa crus-galli*)

Bindweed, field (*Convolvulus arvensis*)

Buckwheat, wild (*Fagopyrum esculentum*)

Cocklebur, common (*Xanthium strumarium*)

Crabgrass (*Digitaria* spp.)

Dodder (*Cuscuta* spp.)

Foxtail spp. (*Alopecurus* spp.)

Knotweed, prostrate (*Polygonum aviculare*)

Kochia (*Bassia scoparia*)

Lambsquarters, common (*Chenopodium album*)

Mallow, common (Malva neglecta)

Mustard spp.

Nightshade, cutleaf (*Solanum triflorum*)

Nightshade, black (*Solanum americanum*)

Nightshade, Eastern black (*Solanum ptychanthum*)

Nightshade, hairy (*Solanum physalifolium*)

Nutsedge, yellow (*Cyperus esculentus*)

Oat, volunteer (*Avena sativa*)

Oat, wild (*Avena fatua*)

Pigweed spp. (*Amaranthus* spp.)

Potato, volunteer

Puncture vine (*Tribulus terrestris*)

Purslane, common (*Portulaca oleracea*)

Quackgrass (*Elymus repens*)

Sandbur, field (*Cenchrus longispinus*)

Smartweed spp. (annual) (*Polygonum* spp.)

Sowthistle, annual (*Sonchus oleraceus*)

Sunflower, wild (*Helianthus annuus*)

Thistle, Canada (*Cirsium arvense*)

Thistle, Russian (*Salsola tragus*)

Wheat, volunteer (*Triticum aestivum*)

Vertebrate pests

Gophers (*Thomomys* spp.)

Mice (many species)

Voles (many species)

Deer

Potato pest management timing by crop stage

Field preparation to preplant

Aphids, beet leafhopper, psyllid, Colorado potato beetle, wireworms

Nematodes

Fusarium dry rot, pink rot, Rhizoctonia canker, ring rot, silver scurf, Verticillium wilt, late blight

Weeds

Gophers, mice, voles

Planting to preemergence

Aphids [Potato virus Y (PVY) and Potato leafroll virus (PLRV)], psyllid, beet leafhopper, Colorado potato beetle, wireworm

Nematodes

Fusarium dry rot, late blight, pink rot, powdery scab, Pythium leak, Rhizoctonia canker, bacterial rots (ring rot and soft rots), **silver scurf**

Weeds

Emergence to row closure

Early blight, late blight, white mold, brown spot, black dot, pink rot, Pythium leak

Colorado potato beetle, Psyllid, beet leafhopper, aphids, tuberworm, Lygus

Nematodes

Weeds

Gophers, mice, voles

Row closure to harvest

Beet leafhopper, psyllid, tuberworm, aphids, loopers and other caterpillars, Colorado potato beetle, tuberworm, flea beetles, spider mites, thrips, aphids, stinkbugs, Lygus

Nematodes

Early blight, white mold, late blight, Botrytis, pink rot, Pythium leak, periderm disorder syndrome, Verticillium/early die (water management)

Weeds

Harvest to post-harvest

Tuberworm

Fusarium dry rot, tuber rots (Pythium leak, pink rot, soft rot), **silver scurf, late blight, tuber rot**

Weeds

Major potato pest descriptions

Insects and nematodes

Aphids

Green peach aphid (*Myzus persicae*)

Potato aphid (*Macrosiphum euphorbiae*)

For pest description information, see: pnwhandbooks.org/insect/vegetable/irish-potato/potato-irish-aphid

Green peach aphid and **potato aphid** are the two most common aphid species in potato. Potato aphid is more common in the spring and fall, while green peach aphid peaks during July and early August. Large populations of aphids can cause damage and yield impacts through direct feeding, but their main economic impact is due to their ability to transmit viruses such as potato leaf roll virus and Potato virus.

Caterpillars

Cutworm (*Xestra c-nigrum*)

Armyworm (*Mamestra configurata*)

Alfalfa Looper (*Autographa californica*)

Cabbage looper (*Trichoplusia ni*)

For pest description information, see: pnwhandbooks.org/insect/vegetable/irish-potato/potato-irish-cutworm-armyworm and pnwhandbooks.org/insect/vegetable/irish-potato/potato-irish-looper

Several species of moth caterpillars (order *Lepidoptera*) can sometimes be found in potatoes, but recent research has shown that the most important pests in the Pacific Northwest are **bertha armyworm, spotted cutworm**, and **cabbage looper**.

Larvae of these species appear as caterpillars with three pairs of true legs in the front, and five pairs of pro-legs behind (cutworms and armyworms) or three pairs of pro-legs behind (loopers). Potatoes can tolerate some caterpillar defoliation without loss in marketable yield.

Colorado potato beetle (*Leptinotarsa decemlineata*)

For pest description information, see: pnwhandbooks.org/insect/vegetable/irish-potato/potato-irish-colorado-potato-beetle

The Colorado potato beetle is a yellow-and-black-striped beetle, about 0.5-inches long and 0.25 inches wide. Larvae are reddish-orange, with two rows of black spots on each side. Yellow egg clusters are found on leaves. Adults and larvae can cause complete defoliation and nearly complete crop loss if allowed to reproduce unchecked, which has been observed in areas with widespread insecticide resistance. Larvae are more voracious than adults, eating up to 40 sq cm of leaves or green tissue.

Flea beetles (*Epitrix* spp.)

For pest description information, see: pnwhandbooks.org/insect/vegetable/irish-potato/potato-irish-flea-beetle

Three species of flea beetles, the western potato flea beetle *(E. subcrinita)*, the tobacco flea beetle *(E. hirtipennis)*, and the tuber flea beetle *(E. tuberis)*, are known foliage feeders in Pacific Northwest potato fields, especially west of the Cascades. Of these, only the tuber flea beetle seriously injures potato tubers.

Oregon surveys indicate that only the western potato flea beetle is in potato fields of Malheur, Baker and Klamath counties. Although once in heavy numbers in Deschutes, Crook and Jefferson counties, the tuber flea beetle has not been a problem in these areas for several years. West of the Cascades, tuber flea beetle has become a serious problem in some areas, particularly the Skagit Valley of Washington.

Adults chew minute circular holes on the leaves, producing a "shot-hole" pattern. Tuber damage consists of shallow subsurface wavy furrows. The damage to potato tubers by the tuber flea beetle is almost identical to that of symphylans and is difficult to distinguish. Both tuber flea beetles and symphylans sometimes live in the same fields.

Beet leafhopper (*Circullifer tenellus*)

For pest description information, see: pnwhandbooks.org/insect/vegetable/irish-potato/potato-irish-leafhopper

The most important leafhopper for potato producers in the Pacific Northwest is the beet leafhopper due to its ability to transmit the beet leafhopper virescence agent phytoplasma. This leafhopper varies in color but is always one of the smaller species and lacks prominent spots or other dorsal or head markings. Phytoplasmas can cause a wide range of symptoms in potatoes that are collectively referred to as "purple top," including leaf curling and purpling, aerial tubers, chlorosis, and early senescence. Beet leafhopper is the most important vector of BLTVA in the Columbia Basin of Oregon and Washington. Most BLTVA infection occurs early in the season, during May and June, although some evidence suggests damaging infections in July.

Lygus bugs (*Lygus* spp.)

For pest description information, see: https://pnwhandbooks.org/insect/vegetable/irish-potato/potato-irish-lygus-bug

Adults are less than 0.25-inch-long and marked with a "V" shaped or triangular mark on the back. Color ranges from light green to shades of brown or black. Nymphs are 0.04 to 0.25-inch-long, green or yellow-green, with black spots on the back. Adults and nymphs damage plants by inserting their mouth parts into the plant tissue and sucking juices. Damage symptoms include flagging of leaflets, leaves, or small stems early in the season, and leaf distortion or tattering later on. Wilted leaves or stems may die, and photosynthesis is reduced where growth is distorted. Adults and nymphs prefer to feed on the top third of the plant canopy. Symptoms on some potato varieties includes "purple-top" stems above feeding sites that is not associated with pathogens.

Potato/Tomato psyllid (*Bactericera cockerelli*)

For pest description information, see: pnwhandbooks.org/insect/vegetable/irish-potato/potato-irish-psyllid

Adult psyllids resemble miniature cicadas, while the immature stages are scale-like and mostly sedentary. Feeding at immature stages sometimes causes a physiological foliage disorder known as "psyllid yellows" in potatoes. Symptoms of psyllid yellows are similar to those caused by phytoplasmas transmitted by leafhoppers. No laboratory test can confirm psyllid yellows; rather, symptomatic plants that test negative for phytoplasmas often are assumed to have psyllid yellows.

Potato psyllid transmits a bacteria-like organism (*Candidatus Liberibacter solanacearum*) that causes a syndrome called "zebra chip," named after the characteristic discoloring of the tuber flesh in affected plants. This disease has been most severe in the Southwest U.S. and in Mexico, Central America and New Zealand. In 2011, this disease was first found in many potato fields in Oregon, Washington and Idaho. Zebra chip is now an annual pest issue for Pacific Northwest potato growers, but its prevalence varies between years.

Grey field slug (*Deroceras reticulatum*)

For pest description information, see: pnwhandbooks.org/insect/vegetable/irish-potato/potato-irish-slug

This slug is native to northern Europe, North Africa and the Atlantic Islands. It is present in the U.S. in several states and was first reported damaging storage potatoes in 2017. Little is known about the biology of the species related to potatoes in the field and in storage.

These slugs damage harvested potatoes by building thick galleries that are different than the ones described for wireworms or tuberworms. In general, the entry hole is round and slugs of different sizes can be found inside tubers. Galleries can be subsequently infested by flies or beetles.

Spider mite (*Tetranychus urticae*)

For pest description information, see: pnwhandbooks.org/insect/vegetable/irish-potato/potato-irish-spider-mite

Spider mites are tiny, spiderlike animals that produce webs and are generally found on the undersides of leaves. Mite damage in potatoes is a loss of photosynthetic ability due to stippling and sometimes bronzing of the leaves. Mites reproduce rapidly and can build up to unmanageable populations in a few days under the right conditions. What causes this population explosion and allows the mites to take down fields is uncertain, but application of nonselective pesticides, such as pyrethroids, certain carbamates, and organophosphates, can negatively impact mite predators and allow spider mites to increase. Dusty, hot, dry weather can also lead to population growth. In most cases, mite outbreaks in potatoes are an induced problem, brought on by management practices aimed at other pests.

Stink bugs (several species from the *Pentatomidae* family)

For pest description information, see: pnwhandbooks.org/insect/vegetable/irish-potato/potato-irish-spider-mite

Stink bugs are pests of potatoes only in isolated pockets in the PNW. It is important to note that there are two species of large stink bugs in potatoes that are predators of Colorado potato beetle and caterpillars. Photos of these beneficial stink bugs can be seen at: http://www.nwpotatoresearch.com/IPM-StinkBugs2.cfm.

Stink bugs that damage potatoes are usually large (0.37 inch), green, shield-shaped bugs. In the Columbia Basin, *Chlorochroa* is a common genus affecting potatoes. They feed by sucking plant sap. Stink bug damage usually causes flagging of leaflet, leaf or stem, similar to that caused by lygus. Damage caused by feeding at the base of a leaf can cause the entire leaf to wilt.

Thrips

Onion thrips (*Thrips tabaci*)

Western flower thrips (*Frankliniella occidentalis*)

For pest description information, see: pnwhandbooks.org/insect/vegetable/irish-potato/potato-irish-thrips

Thrips are tiny, slender-bodied insects (0.5 to 1.0 mm in length). Wings may be present or absent, and are unlike normal insect wings; thrips' wings are essentially thin rods lined with long hairs. Populations of thrips are low in the early spring but build up over time and can become very dense. Thrips feed on leaves and flowers, but in potatoes are most commonly found on the underside of leaves. Thrips feed on potato leaves by sucking out plant cell contents. Damage to potato leaves looks somewhat like mite damage, in that there are often small patches of damaged leaf tissue that are paler than surrounding healthy tissue.

Tuberworm (*Phthorimaea operculella*)

For pest description information, see: pnwhandbooks.org/insect/vegetable/irish-potato/potato-irish-tuberworm

During the growing season, tuberworm caterpillars feed as leaf miners inside leaves. They later live either inside stems or within groups of leaves tied together with silk. Tubers are also a food source for the caterpillars, especially exposed tubers and those within 2 inches of the soil surface. Larvae can infest tubers by leaving the foliage and finding available tubers to invade, or adults may find exposed tubers for egg laying. Regardless of the method, tuber damage is the main concern with tuberworms.

Tuber damage is often near the surface, consisting of broad, flat tunnels or furrows in the skin. Caterpillars may also burrow deep into tubers. Tunnels left by tuberworms look dirty, and their openings may be marked by collected droppings of the caterpillar.

Wireworms (*Limonius* spp. and *Agriotes* spp.)

For pest description information, see: pnwhandbooks.org/insect/vegetable/irish-potato/potato-irish-wireworm

Wireworms are the most important soil-dwelling insect pests infesting crops in the Pacific Northwest. The adults, known as click beetles (*Elateridae* family), do little or no damage. The larval or immature stages cause major damage to seedlings and the underground portions of many annual crops including potato. The larvae are shiny white at first, but later become straw colored or light brown. They look wiry and are about 1 inch long when mature.

Several kinds of potato-infesting wireworms are in the Pacific Northwest. Those causing the most damage in irrigated land are the Pacific Coast wireworm (*Limonius canus*), the sugar beet wireworm (L. *californicus*), the western field wireworm (*L. infuscatus*) and the Columbia Basin wireworm (*L. subauratus*). Of these, Pacific Coast and sugar beet wireworms are the most common species. Land with annual rainfall less than 15 inches may be infested with the Great Basin wireworm (*Ctenicera pruinina*). As a result, there may be serious damage when irrigated crops are grown on sagebrush or dry wheat land. This species tends to disappear after a few years of intensive irrigation but may be replaced by the more serious *Limonius* spp., which favor moist conditions. West of the Cascade Mountains, other species of wireworms, including *Agriotes* spp., are pests.

Nematodes

For pest description information, see: pnwhandbooks.org/plantdisease/pathogen-articles/common/nematodes

Root knot nematodes (*Meloidogyne hapla, M. chitwoodi*)

Root lesion nematodes (*Pratylenchus neglectus*)

Stubby root nematodes (*Paratrichodorus* spp. and *Trichodorus* spp.)

Pale cyst nematodes (*Globodera pallida*)

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.) and stubby-root nematodes (*Trichodorus* and *Paratrichodorus* spp). 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, which causes corky ringspot in potatoes.

Diseases and pathogens

Black dot (*Colletotrichum coccodes*)

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-black-dot

Black dot is caused by *Colletotrichum coccodes*, a fungus with a wide host range in many potato-growing regions. Leaves of affected plants may progressively yellow and wilt. The stem yellows, browns and dries; then sclerotia appear at the base up to several inches above soil level. Other symptoms, such as dark, necrotic, sunken lesions on stems, petioles and veins, may occur also. Lesions may advance, causing the affected stem to die back or completely wilt. Infection on tubers impact, the surface appearance and can sometimes be confused with silver scurf.

Corky ringspot (*Tobacco rattle virus*)

For pest description information, see pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-corky-ringspot

Corky ringspot is a tuber disorder caused by the tobacco rattle virus, which is transmitted by stubby-root nematodes *Trichodorus* spp. and *Paratrichodorus* spp. The disease is widely scattered in the Pacific Northwest and can cause extensive damage. In central Oregon, corky ringspot has been severe when potatoes follow mint. All currently grown cultivars appear susceptible.

Internal symptoms are generally necrotic arcs or brown spots, but larger necrotic areas can sometimes be seen. There are usually no apparent foliage symptoms. Corky ringspot can be confused with symptoms caused by potato mop-top virus and potato virus. Arcs on the surface of tubers can be sometimes seen in smooth skin cultivars.

Early blight and brown spot (*Alternaria* spp.)

For pest description information, see pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-early-blight

The fungus that causes brown spot, *Alternaria alternata*, is closely related to early blight (caused by *Alternaria solani*), and symptoms are also very similar. Successful control of both pathogens depends on accurate identification and a tailored approach. Like early blight, the brown spot pathogen overwinters as spores and mycelia on the infected tissue of various solanaceous hosts. Warmer temperatures in spring trigger fruiting and the release of spores from both fungi, which are moved by wind and water onto potato plants. When moisture is available, the spores germinate and penetrate potato tissue, often through existing wounds. The two pathogens create small, dark, bullseye-like spots on lower leaves that get progressively larger as they advance.

Alternaria solani and *Alternaria alternata* are found primarily under sprinkler irrigation. Reduced fertility is often associated with infection. *Alternaria alternata* can sometimes be found in leaf and stem spot outbreaks and is more commonly found now than prior to 2000, probably due to repeated use of new fungicides and the development of resistance.

Fusarium dry rot (*Fusarium* spp.)

For pest description information, see https://pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-fusarium-dry-rot

Fusarium dry rot can be caused by several *Fusarium* spp., including *F. sambucinum*, *F. coeruleum* and *F. avenaceum*. These fungi survive on refuse and live in soil. Infections can originate from infested seed tubers. Tuber rot usually does not occur unless the tuber is injured during harvest. Wounds provide a way for the fungus to enter the tuber. Dry rot is one of the most common storage and seed piece diseases. Fusarium dry rot leads to secondary infections by soft rot bacteria.

Fusarium wilt (*Fusarium* spp.)

For pest description information, see pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-fusarium-wilt

Fusarium wilt can be caused by several *Fusarium* sp., including *F. avenaceum*, *F. oxysporum*, and *F. solani*. These fungi survive in infected plant parts. The fungi cause mid- to late-season bronzing, yellowing and reddish-to-purple coloring in the top leaves. Vascular tissue of stems, roots and leaf petioles turns brown with some brownish flecking of the pith. Symptoms are similar to Verticillium wilt. Tubers show a sunken brownish discoloration at the stem end.

Late blight (*Phytophthora infestans*)

For pest description information, see pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-late-blight

Late blight is caused by a fungus-like microorganism, *Phytophthora infestans*, which can be blown in as spores with rainstorms or survive on seed potatoes or in culled tubers or tubers left in harvested fields. Tubers can become infected throughout their development, including harvest and storage. Under cool, wet conditions, sporangia can produce swimming spores (zoospores) and spread to healthy tissue. The leaf or stem is colonized quickly, and large portions become necrotic as the microbe advances. With favorable conditions, the pathogen can complete one cycle in as little as four days, so many cycles can occur in the growing season. Indirect damage can occur with secondary infection by soft rot bacteria, which can spread to other tubers below in the pile. This can be a very serious problem in storage.

Most isolates are resistant to mefenoxam and metalaxyl products (Ridomil, others), and their use is not recommended. The occurrence of a second mating type allows for the formation of a different survival structure, the oospore, providing an additional means for the fungus to overwinter, this time in the soil. The existence of compatible mating types also brings the risk of new strains that could be more difficult to control.

Nearly all potato cultivars are susceptible to late blight. Cultivars ‘Norchip,’ ‘Hilite,’ ‘Russet Norkotah,’ ‘Superior,’ ‘Shepody,’ and ‘Red LaSoda’ are more susceptible than Russet Burbank. The cultivar White Rose is similar to Russet Burbank in susceptibility. Cultivars ‘Norkotah’, ‘Ranger Russet’, and ‘Shepody’ are especially susceptible to late blight tuber rot. The disease has been found throughout the Pacific Northwest. The disease is often found in the Willamette Valley of Oregon and in northwestern Washington. Since 1991, almost yearly outbreaks have occurred in the Columbia Basin of Oregon and Washington. The disease is less often seen in Idaho and seldom seen in central Oregon or Klamath Falls. Fields should be scouted early and continuously, and the use of fungicides is essential.

Pink rot (*Phytophthora erythroseptica*)

For pest description information, see pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-pink-rot

Pink rot is caused by *Phytophthora erythroseptica*, a soilborne fungus-like organism. The disease is directly associated with high soil moisture. Pink rot often invades tubers at the stolon end and is characterized by a diagnostic pink color which is visible within several minutes after cutting an infected tuber. Like Pythium leak, pink rot can create a secondary problem in storage by encouraging the development and spread of soft rot. Pink rot does not spread in storage by spore movement but grows from tuber to tuber.

Potato leafroll virus (Genus: *Polerovirus*)

For pest description information, see pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-potato-leafroll-virus-leaf-roll

The Potato leafroll virus (is transmitted by at least 10 species of aphids. Once an aphid acquires the virus, it can transmit it for life, but it can't pass it on to its offspring. The green peach aphid is the most important vector in our area. Infection may come from plants grown from infected tubers or from current season infection by aphids bringing the virus in from other sources. Potential damage is greatest from planting infected seed tubers, since this provides a source of the virus in the potato field. Epidemics may be generated from as few as one infection center (e.g. ,one infected tuber) per acre when aphids are not controlled. The amount of virus allowed in certified seed potatoes differs among states.

Yield reduction (reduced numbers and size of tubers) is greatest for plants derived from infected seed tubers, followed by plants initially virus free but infected early in the season from infective aphids. Mature plants show resistance. Besides yield loss, important losses also occur from tuber net necrosis, which occurs only from current season infection, not seedborne infection. Affected tubers are not suitable for fresh market, processing or seed. Due to the use of new systemic insecticides in potatoes and improvements in seed lot testing, PLRV is seldom seen in seed or in commercial plantings across the Northwest.

Potato mop-top virus (Genus: *Pomovirus*)

For pest description information, see pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-potato-mop-top-virus

The Potato mop-top virus is a pomovirus vectored by the soilborne organism, *Spongospora subterranea*, which causes powdery scab of potato. The virus can be found in scab spore-balls and can remain viable in the field 18 years or longer without the plant host. PMTV can also be tuber-borne.

Until 2001, PTMV was considered an exotic pathogen, found primarily in cooler growing regions around the world. It was detected in a few lots of processing potatoes from Idaho, Oregon and Washington in 2001 but not in 2002. This virus has now been confirmed in many potato production areas in the United States and is commonly found where powdery scab is present. Tuber symptoms are not commonly found. Yield losses can be up to 20% in highly sensitive cultivars. It can be confused with corky ringspot and diagnostic tests are usually needed to determine whether PMTV is present.

Potato virus Y (Genus: *Potyvirus*)

For pest description information, see pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-latent-viruses

Potato virus Y infection of potato plants results in a variety of symptoms depending on the viral strain. The mildest of these symptoms is yield loss, but the most detrimental is potato tuber necrotic ringspot disease. Necrotic ringspots render potatoes unmarketable and can result in a significant loss of income. PVY is transmitted by aphids and can be transmitted to some degree through mechanical contact between plants (machinery, etc.) and from season to season in seed potatoes. This means that production of seed potatoes for several consecutive generations will lead to a progressive increase in viral load and subsequent loss of crop. A limited-generation certified seed system is essential to controlling PVY.

Powdery mildew (*Golovinomyces orontii*)

For pest description information, see pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-powdery-mildew

The fungus, *Golovinomyces orontii* (formerly *Erysiphe cichoracearum*and *Euoidium violae*, the asexual stage), is reported throughout the world on a wide range of hosts, but the strain on potatoes is a distinct physiologic race. Furrow-irrigated potatoes are more likely to show infection than sprinkler-irrigated.

Powdery mildew is not always as noticeable on potatoes as on other plants. It first appears on potatoes as brown lesions of various sizes on stems and petioles. Lesions coalesce to form short streaks or stippled patches. The white powdery coating typical of powdery mildews on most other hosts frequently does not develop on potatoes, but if the air is moist, diseased leaves eventually may be covered by it. Leaves and stems are killed, and only the tip of the plant may remain green. In severe cases, vines collapse. Infection and vine collapse may be over large areas of the field. This is only an occasional problem in potatoes.

Powdery scab (*Spongospora* subterranean)

For pest description information, see pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-powdery-scab

Powdery scab is caused by a fungus-like soilborne organism, *Spongospora subterranea*, that is carried on seed and can survive three to 10 years or longer as cysts in soil. This organism also transmits Potato mop top virus. It usually is evident that the potato’s epidermis has broken away to expose the powdery mass of cysts, making thin-skinned varieties unmarketable. Russet varieties are more resistant to tuber lesions. Small galls and warts form on the roots of all potato varieties and other plants in the potato family. Although this organism has been present in North America since the early 1900s, it has only become of widespread concern during the last 20 years.

Purple top (a member of phytoplasma group 16SrVI)

For pest description information, see pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-purple-top

Purple top is caused by a phytoplasma, also called BLTVA for beet leafhopper-transmitted virescence agent (a member of phytoplasma group 16SrVI in the Pacific Northwest.

Phytoplasmas can cause a wide range of symptoms in potatoes that are collectively referred to as “purple top,” including leaf curling and purpling, aerial tubers, chlorosis, and early senescence. Symptoms of purple top resemble PLRV, zebra chip and other vascular diseases with rolled leaves, a purplish cast, shortened internodes, and the formation of aerial tubers.

Pythium leak (*Pythium* spp.)

For pest description information, see vegetablemdonline.ppath.cornell.edu/NewsArticles/Potoato_Pink_Leak.htm

Pythium leak, caused by *Pythium* spp., is often described as a "shell rot," but the term "leak" comes from the extremely wet nature of the rotted tissues. *Pythium* primarily invades tubers through harvesting wounds, and post-harvest rot often develops in transit or in storage. Excessive moisture (poor drainage, excessive precipitation or irrigation) and high pulp temperatures at harvest play key roles in tuber infection. Further losses may occur in storage due to secondary bacterial infections of the damaged tissue. This disease also tends to cause a gray-brown-black rot in the interior of the tuber, leaving the outer cortex, or "shell," of the tuber intact.

Rhizoctonia canker and black scurf *(Rhizoctonia solani)*

For pest description information, see pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-rhizoctonia-canker-black-scurf

Rhizoctonia canker is caused by *Rhizoctonia solani*, a fungus that is a common soil inhabitant and has a wide host range. While seed pieces can carry the fungus, soilborne inoculum can be equally as damaging.

When sprouts are infected before emergence, they may be girdled and killed by reddish-to-dark-brown girdling cankers found on the stems at or below the soil surface. Stems seem to become more resistant to infection once they emerge. If plants are infected later in their development, they may have reddish-brown to brown lesions on stems, stolons, tubers, and roots. Leaf curl, like that caused by potato leafroll virus, may occur. Tubers may have black bodies (scurf) on the surface, and they are not easily removed. While the bodies do not affect the tuber's interior, enough of them on the surface of potatoes being grown for the fresh market will cause rejection.

Ring rot (*Clavibacter michiganensis subsp. sepedonicus*)

For pest description information, see pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-ring-rot

Ring rot is caused by a bacterium, *Clavibacter michiganensis* subsp. *sepedonicus* (formerly *Corynebacterium sepedonicum*), which overwinters in infected tubers or as a dried slime on machinery and sacks, in storage houses, etc. It does not overwinter in soil except in infected volunteer plants. Knives used during seed-cutting operations can easily spread ring rot bacteria from infected tubers to healthy tubers.

Symptom expression varies by cultivar. Foliage generally does not show symptoms until mid-to-late in the growing season. Ring rot in tubers may not develop until they have been in storage several months, or it may be present at digging or before. When infected tubers are cut near the stem end, ring rot symptoms may appear as yellow or light brown rings of cheesy consistency in the tuber's vascular ring. In advanced tuber rot, dry gray pockets of decayed tissue surround the vascular ring. Secondary rots may completely destroy the tuber, either in the soil or in storage.

Rots

Bacterial soft rot (usually *Pectobacterium atrosepticum*)

Blackleg (usually *Pectobacterium atrosepticum*)

Lenticel rot *(P. carotovorum* subsp. *carotovorum*)

For pest description information, see pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-bacterial-soft-rot-blackleg-lenticel-rot

The bacterium, *Pectobacterium carotovorum* subsp. *atrosepticum* (syn. *Erwinia carotovora* subsp. *atroseptica*), is usually associated with blackleg and soft rot in storage while *P. carotovorum* subsp. *carotovorum* (syn. *E. c. subsp. carotovora*) is associated with aerial stem rot, lenticel rot and soft rot. Moist, cool (below 70°F) conditions enhance blackleg while warmer conditions (70°F to 80°F) are optimal for soft rot. Another bacterium, *Dickeya dianthicola*, has been found in the eastern United States and is associated with poor stands, blackleg under warmer temperatures, and decayed daughter tubers in affected fields. The bacteria can be splashed onto foliage by rain or irrigation causing aerial stem rot, and foliar infections can also be caused when bacteria are present in irrigation water. The principal source of inoculum for blackleg is contaminated seed tubers. The bacteria can be spread among seed pieces by machinery and handling, moving from diseased to healthy seed pieces during cutting. However, these bacteria can survive on many weedy plants (nightshades, lambsquarters, pigweeds, purslane, etc.). They also reside in tuber lenticels without causing symptoms but can cause disease if tubers with lenticel populations are used for seed.

Common scab (*Streptomyces* scabies)

For pest description information, see https://pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-scab-common

Common scab is caused by *Streptomyces* spp., filamentous bacteria that live in soil and on diseased tubers. Scab-causing *Streptomyces* can also infect carrots, red beets, some weeds and other crops. Neutral or alkaline soils favor scab development. Russet cultivars are generally less affected than smooth-skinned cultivars. Under some conditions, soils with high levels of undecomposed organic matter can have more severe disease. This disease can be confused with powdery scab.

Silver scurf (*Helminthosporium solani*)

For pest description information, see pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-silver-scurf

Silver scurf is caused by a fungus, *Helminthosporium solani*, that is spread primarily by infected seed but can survive a short time on potato debris in soil. The disease can worsen in storage, beginning three to four months following storage, and ultimately result in substantial infection with longer storage. Humidity above 90% favors this disease. Smooth-skin cultivars, particularly when grown in cooler soils with higher consistent soil moisture, may be severely infected at harvest. Russet cultivars are apparently not as susceptible. This disease is only a surface problem but nevertheless can cause substantial losses by disfiguring the tuber surface and can occur with other tuber blemish diseases such as black scurf or black dot. Tuber infections can lead to increased weight loss in storage.

Small, light-brown, circular spots form that tend to grow together and cover large areas of tubers. When lesions are wet, they take on a silvery color that gives the disease its name. Silver scurf can be confused with black dot.

Verticillium wilt (potato early dying) (*Verticillium dahliae*)

For pest description information, see pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-verticillium-wilt-potato-early-dying

Verticillium wilt is caused by a fungus, *Verticillium dahliae*, which survives in soil or in infected plant parts. It infects through roots and invades the plant's water-conducting tissues, ultimately causing wilt. Disease severity is usually proportionate to the inoculum density of the fungus in the soil. The cultivars 'BelRus', 'Shepody', 'Russet Norkotah', and 'Superior' are a few of many susceptible cultivars. The cultivar 'Russet Burbank' is considered moderately resistant. The cultivar 'Ranger Russet' is more resistant, but yield loss still occurs. An interaction with this disease and lesion nematodes (*Pratylenchus* *penetrans*) can cause further damage. Other disease organisms are involved with potato early dying, including the causal agents of black dot and bacterial soft rot, but Verticillium is the most important component.

Vines prematurely yellow and die. Later, wilted or dead plants stand upright. This disease can greatly reduce yield.

White mold (*Sclerotinia* stem rot) (*Sclerotinia sclerotiorum*)

For pest description information, see https://pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-white-mold-sclerotinia-stem-rot

White mold is caused by a fungus, *Sclerotinia sclerotiorum*, that overwinters in soil as hard black sclerotia. Sclerotia germinate in spring and produce small, inverted, mushroom-like structures called apothecia that shoot spores into potato foliage. Spores produced in the potato field are more important for infection than those from outside the field. Petals on flowering potato plants are especially susceptible and important in the disease cycle. Petals fall and naturally become associated with stems. Infected petals are an initial source of nutrient for the fungus, which then infects the stems. Spores can also infect stems directly. Sclerotia also can germinate directly and infect the plant. Though widespread, and at times appearing to be substantial due to obvious damage in the field, yield impacts are generally marginal in most.

Zebra chip (*Candidatus Liberibacter solanacearum*)

For pest description information, see https://pnwhandbooks.org/plantdisease/host-disease/potato-solanum-tuberosum-zebra-chip

Zebra chip is caused by a phloem-limited bacterium, *Candidatus Liberibacter solanacearum*, which is transmitted by the potato psyllid (*Bactericera cockerelli*). Optimum temperature for disease development is 80°F to 90°F and transmission by the potato psyllid can occur at temperatures as cool as 54°F. In addition to potato, other cultivated and wild solanaceous species are host to this pathogen. Zebra chip foliar symptoms closely resemble potato purple-top, a phytoplasma-caused disease, and psyllid yellows, a symptom resulting from feeding by the potato psyllid. Zebra chip is named after the characteristic discoloring of the tuber flesh in affected plants. This disease has been most severe in the Southwest U.S. and in Mexico, Central America and New Zealand. In 2011, this disease was found for the first time in many potato fields in Oregon, Washington and Idaho. Zebra chip is now an annual pest issue for Pacific Northwest potato growers, but its prevalence varies between years.

Weeds

For specific weed identification, refer to *Weeds of the West Guide:* wyoextension.org/agpubs/pubs/wsws-1.pdf

Barley (*Hordeum vulgare*) (volunteer)

Barnyardgrass (*Echinochloa crus-galli*)

Bindweed, field (*Convolvulus arvensis*)

Buckwheat, wild (*Fagopyrum esculentum*)

Cocklebur, common (*Xanthium strumarium*)

Crabgrass (*Digitaria* spp.)

Foxtail spp. (*Alopecurus* spp.)

Knotweed, prostrate (*Polygonum aviculare*)

Kochia (*Bassia scoparia*)

Lambsquarters, common (*Chenopodium album*)

Mallow, common (*Malva neglecta*)

Mustard spp.

Nightshade, cutleaf (*Solanum triflorum*)

Nightshade, black (*Solanum americanum*)

Nightshade, Eastern black (*Solanum ptychanthum*)

Nightshade, hairy (*Solanum physalifolium*)

Nutsedge, yellow (*Cyperus esculentus*)

Oat, volunteer (*Avena sativa*)

Oat, wild (*Avena fatua*)

Pigweed spp. (*Amaranthus* spp.)

Puncture vine (*Tribulus terrestris*)

Purslane, common (*Portulaca oleracea*)

Quackgrass (*Elymus repens*)

Sandbur, field (*Cenchrus longispinus*)

Smartweed spp. (annual) (*Polygonum* spp.)

Sowthistle, annual (*Sonchus oleraceus*)

Sunflower, wild (*Helianthus annuus*)

Thistle, Canada (*Cirsium arvense*)

Thistle, Russian (*Salsola tragus*)

Wheat, volunteer (*Triticum aestivum*)

An effective weed management program considers the type of weeds present, crop rotation, cultivation, available herbicides and the competitive ability of the potato crop. Competition from early season weeds will reduce yields if they are not controlled within one to six weeks after potatoes emerge. Weeds that emerge after vines have covered the rows usually will not compete with the potato crop; however, they can serve as hosts for diseases and viruses as well as insect vectors. Weeds may reduce yields by interfering with harvest and can produce seed that will cause infestation of subsequent crops. Weeds frequently become more serious if crop growth is delayed by adverse conditions early in the season. Weed problems can be reduced by establishing a vigorous stand of potatoes. Control methods may need to be more aggressive in potato varieties which do not close over the rows relatively quickly or do not close at all, which may include seed production potatoes.

Crop rotation is useful in controlling difficult weed problems because it allows for a greater variety of weed control methods in the rotation crops. Crop rotations can also help to control disease and nematodes. Cultivation during field preparation, and after planting but before potato emergence, can also greatly reduce weed populations. Many crops are used in the Pacific Northwest as rotation crops with potato. Green manure cover crops, including mustards, radish and Sudan grass, are commonly grown in July–September and are worked into the soil in the fall. Other cover crops, often cereals such as wheat and barley, are grown during the winter until just prior to potato planting. Care must be taken to choose potato herbicides that can be safely used in a rotation with other crops.

When carefully used, available herbicides control most annuals that presently infest potato fields, and can control or suppress some perennial weeds such as Canada thistle, yellow nutsedge, quackgrass, johnsongrass and bermudagrass. However, adverse weather conditions, such as unusually high amounts of rainfall immediately following herbicide applications, can result in poor performance and the need for additional applications, or herbicide injury to the crop. This could be due to herbicide solubility, which will vary based on soil type, soil pH, and organic matter content.

Potato pest management activities by crop stage

Field preparation—preplant

The preplant crop stage includes field preparation that can begin as early as July or August of the previous year, through fall, winter and early spring. The stage ends with planting, which generally takes place in March or April. Cover crops and rotation crops might be part of the preplant stage. Green manure cover crops, commonly mustards, radish and Sudan grass, are commonly grown in August–October, and are worked into the soil in the fall. Other cover crops, often cereals such as wheat and barley, are grown during the winter until just prior to potato planting.

Tillage, marking and hilling take place in preparation for new plantings. Fall bedding or 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, adverse temperatures, and even certain pests (such as late blight). Hilling also allows soil to drain and warm more quickly in the spring, facilitating earlier planting.

Fumigation is used during this crop stage to suppress damaging soilborne pests including wireworms and nematodes. Depending on fumigation choice, it can also control diseases such as Verticillium wilt, and offers some preplant weed control.

Fall fumigation, in contrast to spring fumigation, allows for timely planting of the spring crop and is generally more effective. Spring fumigation is dependent on sufficiently warm soil temperatures, thereby potentially postponing planting. For that reason, fall fumigation is often a necessity for long-season cultivars. For newly identified fields and late planting decisions, however, spring fumigation may be required. Most potato acreage in the Pacific Northwest requires fumigation for nematode management. It is estimated that around 90% of the potato acres in Washington are fumigated to control nematodes, wireworms and Verticillium.

Nonfumigant nematicides are also used, which control nematodes either by contact or systemic action, but these options do not provide the same control as fumigation. Weed control is also important for nematode management, as many nematodes have weed hosts. Some herbicides are applied preplant to control weeds and remove cover crops.

Field activities and pest management decisions that occur during preplant

- Cover cropping
- Soil sampling
- Fertilizing
- Tillage
- Field zone mapping
- Preparation activities for fumigation (stubble management, deep tillage, moisture assessment, pre-irrigation)
- Fumigation
- Marking out rows; hilling (sometimes done in the fall in Idaho and southern Oregon); sometimes includes banded fertilizer application
- Herbicide program development

- Herbicide application
- Seed preparation: cutting and “suberizing” (sealing off wounds and damage on cut tubers); treating seed potatoes with insecticide or fungicide or both
- Managing potato seed (storage, temperature)
- Purchasing inputs

PAMS[1] practice	Field preparation through preplant pest management activities	Target pest(s)
Prevention	Use of certified seed; resistant varieties	Viral and bacterial diseases, late blight
	Sanitation: cleaning cutting equipment, discs and other tillage implements	Nematodes, bacterial diseases including ring rot, Fusarium; viral diseases
	Site selection	General pest management
	Field selection for rotation	Weed/volunteer management, reduces disease pressure, weeds
	Cull pile management	Insect and disease control; gophers and voles
Avoidance	Crop rotation	General pest management; soil and plant health
	Use of nonhost cover crops	General pest management including nematodes; soil and plant health
	Trap cropping	Nematodes, insects
	Tillage	Weeds, insects
Monitoring	Wireworm traps	Wireworms
	Soil testing for nematodes, Verticillium, and soil fertility	Nematodes, Verticillium, general pest management
	Resistance assays	Pink rot
	Soil pH	

[1] See Appendix “Using PAMS Terminology.”

PAMS[1] practice	Field preparation through preplant pest management activities	Target pest(s)
Suppression	Growth and incorporation of biofumigant cover crops (mustards, radishes)	Nematodes, Verticillium wilt
	Fumigation: done in the previous year in fall and/or spring of planting year ▪ Chloropicrin (Strike) ▪ 1,3 dichloropropene (Telone) ▪ Metam sodium (Vapam, other trade names) ▪ Metam potassium (K-pam, other trade names) ▪ Telone: used alone, but sometimes used in combination with chloropicrin, or in sequence with metam products	Nematodes, wireworms *Verticillium*, weeds, other soilborne diseases
	Nematicide/insecticide application: ▪ Ethoprop (Mocap): applied preplant or in furrow	Nematodes, wireworms
	Herbicide application: ▪ Carfentrazone ethyl (Aim) ▪ EPTC (Eptam) ▪ Glyphosate (Roundup and others) ▪ Metribuzin (only labeled for this timing in some states) ▪ Paraquat (Gramoxone and others) ▪ S-metolachlor (Dual Magnum) ▪ S-metolachlor + glyphosate (Sequence) ▪ Trifluralin (Treflan, only labeled in some states and only when applied with Eptam)	Cover crops, weeds
	Seed treatment: ▪ Fludioxonil + mancozeb (Maxim MZ) ▪ Imidacloprid (Admire Pro) ▪ Mancozeb + flutolanil (Moncoat MZ) ▪ Mancozeb + bark ▪ Thiamethoxam + fludioxonil (Cruiser Maxx) ▪ Thiamethoxam + fludioxonil + difenoconazole (CruiserMaxx Potato Extreme) ▪ Thiamethoxam + fludioxonil + difenoconazole + sedaxane (CruiserMaxx Vibrance) ▪ Thiamethoxam (Cruiser) ▪ Penflufen + prothioconazole (Emesto Silver) ▪ Mandipropamid (Revus) ▪ Cymoxanil (Curzate) Note: many growers apply their own seed treatments	Colorado potato beetle, aphids, leafhoppers, seed-borne *Rhizoctonia*, *Fusarium*, silver scurf, late blight, general broad-spectrum insect and disease control

[1] See Appendix “Using PAMS Terminology.”

Critical needs for pest management during field preparation to preplant

Research topics

- Determine the value of soil health assessments — which ones to use, how to interpret results, how results translate to production.
- Determine the physical and biological variables that impact soil quality and understand the costs and benefits of measures that improve soil quality.
- Evaluate the reliability and value of soil testing for pathogens such as *Verticillium* and *Rhizoctonia*, and determine how the data can support pest management decision-making.
- Research to determine the impacts of fumigants on beneficial and nontarget insect populations and the consequences for in-season pest suppression.
- Identify effective alternatives to fumigation, including biofumigants and other alternatives that protect beneficial microorganisms, nematodes and insects.
- Determine the impact of high salt index fertilizers on soil physical and biological parameters.
- Investigate the impacts of fumigants and seed treatments on plant health and speed of crop emergence.
- Examine biological soil additives in terms of efficacy, impacts to soil, impacts on emerging plants and potential economic benefits.
- Determine the impacts of calcium additives on plant health.
- Identify organic and nonconventional management programs for potato that might be useful to conventional growers.
- Identify and research effective alternatives to dust-based seed treatments for use by growers.
- Research the of elimination of dust-based seed treatments.

Regulatory actions

- Preserve currently registered management tools and pesticide modes of action for potato.
- Explore and pursue changes in seed certification standards to address *Potato mop top virus* and *Tobacco rattle virus*.

Education

- Educate growers and consultants about the value of soil stewardship.
- Increase education for growers and consultants on fumigation, including how to best target fumigation, best practices for application methods, proper timing, temperature considerations, etc.
- Increase education for growers and consultants on fumigation alternatives, such as biofumigation, as they become available.
- Utilize demonstration trials and other activities to accelerate adoption of new principles and practices related to IPM, soil management, pesticide selection, etc.
- Educate growers on the importance of knowing the quality of purchased seed and being able to assess a seller's plant health certificate.

Planting to pre-emergence (March–May with regional differences)

Depending on planting date, seed condition and degree-day accumulation, there can be anywhere from seven to 35 days between planting and emergence.

Management of seedborne diseases is important at this crop stage. These organisms include fungal, bacterial and viral pathogens. Key seedborne diseases include Potato leaf-roll virus, Potato virus Y, late blight, bacterial ring rot, Rhizoctonia and silver scurf. Unfavorable soil conditions and compromised seed quality can lead to an increase in pathogens that survive in the soil, including *Rhizoctonia*, *Fusarium* dry rot and soft rot.

In fields not fumigated in the fall, nonfumigant nematicides can be used at planting or post planting. In fields that were fumigated in the fall, growers may sample for nematodes again before planting to determine if a nonfumigant nematicide application is warranted.

Seedborne viruses present a unique problem for potato growers because they cannot be controlled directly. Instead, growers manage the associated vectors. Resistant varieties offer simple and economical management of diseases if they are available. Certified and disease/vector-free seed is also important to ensure healthy plants.

Growers drag-off or hill (or do both) before herbicide applications that take place prior to potato emergence. Timing of application cultivation are critical for herbicides that can only be applied before potato emergence. Tillage following an herbicide application can disrupt the placement of the herbicides incorporated into the soil and lead to weed germination and emergence. Herbicides that have no soil activity, such as glyphosate (Roundup and others) and paraquat (various trade names) are used in potatoes after planting but before emergence to control emerged weeds.

Field activities and pest management decisions that may occur during planting through pre-emergence

- Planting (cut or whole potatoes)
- Applying fertilizer
- Hilling
- Reservoir tillage (Dammer Diker—trade name)
- Erosion management and rehilling
- Irrigation
- Dragging or harrowing off hills to speed emergence
- Cultivation
- Herbicide application
- Plant growth regulators

PAMS practice	Planting to pre-emergence pest management activities	Target pest(s)
Prevention	Tillage	Weed suppression
Avoidance	Planting date/timing	General pest management
Monitoring	Monitoring	Weeds
	Monitoring soil temperature and moisture, and seed health	Decay caused by *Phytophthora, Pythium; Rhizoctonia*, seed corn maggot
	Monitoring for plant growth and development	General pest management
Suppression	Fungicide application: preventative; in-furrow ▪ Azoxystrobin (Quadris, others) ▪ *Bacillus subtilis* (Serenade formulations) ▪ Benzovindiflupyr + azoxystrobin (Elatus) ▪ Cyazofamid (Ranman) ▪ Ethaboxam (Elumin)Fluopyram (Velum Prime) ▪ Flutolanil (Moncut) ▪ Fluxapyroxad + pyraclostrobin (Priaxor) ▪ Mefenoxam (Ridomil Gold SL) ▪ Penthiopyrad (Vertisan) ▪ Oxathiapiprolin (Orondis)	*Rhizoctonia*, silver scurf, pink rot, Pythium leak, early blight, white mold
	Nematicide/soil pest control: ▪ Ethoprop (Mocap): nematodes ▪ Fipronil (Regent): wireworms ▪ Fluopyram (Velum prime): nematicide/fungicide ▪ Oxamyl (Vydate): nematodes	Nematodes, wireworms, diseases (white mold, early blight)
	Insecticide application: ▪ Thiamethoxam ▪ Imidacloprid ▪ Clothianidin (not commonly used, expensive) ▪ Cyazypyr (Verimark)	Aphids, Colorado potato beetles, psyllids, beet leafhoppers
	Herbicide application: ▪ Carfentrazone ethyl (Aim) ▪ Dimethenamid-p (Outlook) ▪ EPTC (Eptam) ▪ Ethafluralin (Sonalan) ▪ Flumioxazin (Chateau) ▪ Fomesafen (Reflex) ▪ Glyphosate (Roundup and others) ▪ Linuron (Linex) ▪ Metribuzin (various trade names) ▪ Paraquat (various trade names) ▪ Pendimethalin (Prowl H2O) ▪ Pyroxasulfone (Zidua) ▪ Rimsulfuron (Matrix) ▪ S-metolachlor (Dual Magnum) ▪ S-metolachlor + Metribuzin (Boundary) ▪ Sulfentrazone (Various names; see label for specific states) ▪ Trifluralin (Treflan)	Broad spectrum weed control (grasses and broadleaves)

Critical needs for pest management during planting to pre-emergence

Research topics

- Evaluate the impacts of banded fertilizer mixtures on disease and whether low pH is a possible driver.
- Assess the impacts of banded fertilizer mixtures on pesticide efficacy and the level of interaction and compatibility between the two.
- Identify effective alternatives to neonicotinoids for early season insect control.
- Research effective insecticide, fungicide and herbicide resistance management strategies.
- Encourage development of new pesticide modes of action to combat resistance.
- Prioritize potato weed science and the hiring of more weed scientists.

Regulatory actions

- Register new or additional herbicide modes of action in potatoes using the IR-4 process.
- Address MRL issues during pesticide development and before registration to decrease wait time after registration.

Education

- Conduct resistance-prevention education, particularly for neonicotinoids, but also herbicides and other pesticides with resistance concerns.
- Emphasize developing herbicide programs targeting weeds present in a given field, rather than using the same herbicide program in all potato fields.

Emergence to row closure (April–early/late June)

Growers perform hilling and reservoir tillage when plants are emerging and before they become too large to minimize damage. These tillage operations can control emerged weeds less than 2 inches tall. Some pre- and postemergence herbicides can be applied at this timing and followed immediately by light watering to "set" the herbicide in the germination zone. However, application occurs only after hilling and reservoir tillage so as to not disrupt herbicides with soil activity. Level of control by herbicides with foliar activity can also be impacted when tillage occurs soon after application. Unpredictable early spring weather can complicate field and chemical application activities and may reduce herbicide efficacy.

Irrigation management is important at this stage to protect yield and quality. Too little or excess water can reduce yield and quality by causing tuber malformations and defects, or increased disease problems in the field or in storage. Fertilizer management is also important during this stage.

Field activities and pest management decisions that may occur during emergence to row closure.

- Reservoir tilling (Dammer Diker—trade name)
- Cultivation
- Herbicide applications
- Irrigation
- Fertilization
- Petiole sampling
- Soil sampling
- Fungicide applications
- Crop growth monitoring for timing of pesticide applications
- Water sampling for auditing purposes
- Recordkeeping

PAMS practice	Emergence to row-closure pest management activities	Target pest(s)
Prevention	Cleaning equipment between fields	Weeds, soilborne pathogens
Avoidance	Preservation of beneficial insects through avoidance of early season pyrethroid applications	Insect control
	Crop health management: fertility and nutrition; avoiding crop stress	General pest management
	Moisture management	Diseases
Monitoring	Scouting	Insects, diseases, weeds
	Trapping	Psyllid, beet leafhopper, aphids, tuberworm, Lygus
	Monitoring crop growth and tuber size	Disease management (early blight, white mold, storage diseases [pink rot]); fungicide timing
	Spore trapping for disease/mold prediction	Diseases (late blight)
	Moisture monitoring	Irrigation management to limit diseases such as Verticillium wilt, pink rot, common and powdery scab

PAMS practice	Emergence to row-closure pest management activities	Target pest(s)
Suppression	Rodent control: ▪ Trapping ▪ Zinc phosphide (Pro zap)	Gophers, mice, voles
	Hand weeding or cultivation before row closure	Weeds
	Fungicides (some applications as preventative): ▪ Azoxystrobin (Quadris) ▪ Azoxystrobin + chlorothalonil (Quadris Opti) ▪ Boscalid (Endura) ▪ Fluazinam (Omega) ▪ Fluopyram + pyrimethanil (Luna Tranquility) ▪ Mefenoxam products (Ridomil) ▪ Phosphorous acid-based products (phosphites) ▪ Pyraclostrobin + metiram (Cabrio) ▪ Pyraclostrobin (Headline)	Black dot, late blight, early blight/brown leaf spot, white mold, pink rot, Botrytis, Pythium
	Insecticides:	
	Neonicotinoids, including: ▪ Thiamethoxam (Cruiser products) ▪ Imidacloprid ▪ Clothianidin (not commonly used, expensive) Pyrethroids (not generally applied before row closure in Idaho) Many products used Other products: ▪ Abamectin (Agri-mek) ▪ Spinosad (Blackhawk)	Colorado potato beetle, aphids, psyllids, general early season insect control
	▪ Oxamyl (Vydate) (chemigated)	Nematodes
	▪ Dimethoate ▪ Neonicotinoids ▪ Pyrethroids	Beet leafhoppers
	▪ Dimethoate ▪ Flonicamid (Beleaf) ▪ Flupyradifurone (Sivanto) ▪ Methomyl (Lannate) ▪ Neonicotinoids ▪ Oxamyl (Vydate) ▪ Pymetrozine (Fulfill) ▪ Sulfoxaflor (Transform)	Aphids
	▪ Novaluron (Rimon) ▪ Sulfoxaflor (Transform) ▪ Pyrethroids	Lygus
	Herbicides: ▪ EPTC (Eptam) ▪ Metribuzin ▪ Rimsulfuron (Matrix) ▪ Pendimethalin (Prowl H2O) ▪ S-metolachlor (Dual Magnum) ▪ Grass herbicides: sethoxydim (Poast Plus), clethodim (Select) Note: Only rimsulfuron and metribuzin have foliar activity on emerged broadleaves.	

Critical needs for pest management during emergence to row-closure

Research topics

- Determine action and economic thresholds for all potato insect pests to aid in treatment decision-support.
- Research the effectiveness of owl boxes for vertebrate pest management.
- Identify alternative effective controls for Lygus bug and thrips.
- Evaluate alternatives to mefenoxam for pink rot and Pythium leak management to combat resistance issues.
- Verify efficacy of crop health biostimulants.
- Refine current pest forecasting tools and pest management decision-support tools as they cover potato diseases and integrate with spore trapping efforts and spore risk factors.
- Pursue the use of advanced imaging and new technology for pest scouting, plant health and crop management.
- Research best practices for promoting beneficial insects in potato fields.
- Monitor and characterize herbicide resistance in weed species

Regulatory actions

- Consolidate various auditing requirements to reduce the auditing and paperwork burden on growers. Consider working with international trading partners to certify under one umbrella rather than multiple.
- Improve the MRL system: address MRL issues prior to registration; standardize MRLs across all countries
- Accelerate the MRL process and streamline with the international certification process.

Education

- Educate growers on best practices for efficient compliance with various certification audits.
- Increase education to the general public on the factors impacting potato pest management and highlight examples of stewardship.
- Educate growers and consultants on pesticide selection issues, including: pesticide active ingredients and combination products, resistance management and protection of beneficial insects.
- Educate growers and consultants on proper herbicide timing for best control, including appropriate weed size.

Row closure to harvest (June- September/October)

After row closure, the microclimate in the potato canopy is favorable for many foliar diseases. Fungicide applications are necessary to cover newly developing, unprotected foliage and protect against late blight, early blight, white mold and other foliar diseases. Because fungicide residues are degraded by sunlight, irrigation and rain, repeated applications are necessary.

Potato bloom can begin before or after row closure, with some cultivars blooming more vigorously than others. Any insecticides or fungicides applied during bloom will be used based on label restrictions to protect any visiting pollinators.

Killing potato vines before harvest is a common practice in many areas of the Pacific Northwest; it is useful to hasten tuber maturity and skin set. This is important for disease and bruise protection at and after harvest. For growers practicing vine kill, desiccants are used to kill the living vines. If potatoes are left in the field until full maturity, the canopy dies on its own. Some fields are harvested when the plants are still green and growing, and the tubers are sent directly to processing. This method of early harvesting allows more tolerance for some pests. Decisions about which of these methods to use vary within and among growing operations, and are often made based on current-season pest pressure, intended markets and the expectations of processors and other buyers.

Field activities and pest management decisions that may occur during row closure to harvest.

- Insect/disease/weed scouting
- Irrigation
- Fertilization
- Petiole sampling
- Soil sampling
- Insecticide applications
- Foliar fungicide applications
- Sprout inhibition/size control (MH30)
- Water sampling for auditing purposes
- Recordkeeping

PAMS practice	Row closure to harvest management activities	Target pest(s)
Prevention	Perimeter weed management	Beet leafhopper, aphids
Avoidance	Irrigation management	General pest management
	Avoid pyrethroid sprays if possible to preserve beneficials	Insect control
	Manage foliar nutrient levels to resist disease	Disease management
Monitoring	Assess population densities for treatment decisions	General pest management
	Scouting and monitoring: ▪ Yellow sticky cards for psyllid monitoring ▪ Use of pest alert systems through OSU, WSU, UI ▪ Pheromone trapping ▪ Monitoring for insect pests on foliage: loopers, aphids, lygus and other foliar pests	Psyllid, tuberworm, aphids, loopers and other caterpillars, Colorado potato beetle, flea beetles, spider mite, thrips, stinkbugs, diseases, etc.
	Monitoring for foliar diseases	Disease management
	Moisture monitoring	Irrigation management to limit diseases
	Monitoring for tuber growth and development including defects and soilborne pests	Wireworm, nematode (damage), pink rot, Pythium leak
Suppression	**Insecticides:**	
	Neonicotinoids, including: ▪ Clothianidin (not commonly used, expensive) ▪ Imidacloprid ▪ Thiamethoxam Pyrethroids: ▪ Esfenvalerate (Asana) ▪ Many others Other products: ▪ Chlorantraniliprole (Coragen) (very expensive, not used much) ▪ Oxamyl (Vydate) ▪ Spinosad (Blackhawk)	Colorado potato beetle

PAMS practice	Row closure to harvest management activities	Target pest(s)
Suppression	▪ Oxamyl (Vydate) (chemigated)	Nematodes
	▪ Neonicotinoids ▪ Pyrethroids	Beet leafhopper
	▪ Dimethoate ▪ Flonicamid (Beleaf) ▪ Flupyradifurone (Sivanto) ▪ Methomyl (Lannate) ▪ Neonicotinoids ▪ Oxamyl (Vydate) ▪ Pymetrozine (Fulfill) ▪ Sulfoxaflor (Transform)	Aphid
	▪ Novaluron (Rimon) ▪ Pyrethroids ▪ Sulfoxaflor (Transform)	Lygus
	▪ Abamectin (Agri-Mek) ▪ Flupyradifurone (Sivanto) ▪ Pyrethroids ▪ Spiromesifen (Oberon) ▪ Spirotetramat (Movento) ▪ Sulfoxaflor (Transform) ▪ Flonicamid (Beleaf)	Psyllid, aphid
	▪ Pyrethroids (Warrior common)	Tuberworms
	▪ Chlorantraniliprole (Coragen) ▪ Indoxacarb (Avaunt) ▪ Novaluron (Rimon) ▪ Pyrethroids ▪ Spinosad (Black hawk)	Loopers/armyworms
	▪ Abamectin (Agri-Mek) ▪ Methomyl (Lannate) ▪ Spinosad (Black hawk) ▪ Spirotetramat (Movento) ▪ Spinetoram (Radiant) (not used as commonly as spinosad, which is less expensive)	Thrips
	Miticides: ▪ Abamectin (Agri-Mek) ▪ Bifenazate (Acramite) ▪ Hexythiazox (Onager) ▪ Propargite (Comite) ▪ Spiromesifen (Oberon)	Spider mite

PAMS practice	Row closure to harvest management activities	Target pest(s)
Suppression	**Fungicides:** ▪ Fluazinam (Omega) ▪ Fluazinam + difenoconazole (Omega Top) ▪ Mandipropamid + difenoconazole (Revus Top) ▪ Fluopyram + pyrimethanil (Luna Tranquility) ▪ Boscalid (Endura) ▪ Penthiopyrad (Vertisan) ▪ Fluxapyroxad + pyraclostrobin (Priaxor) ▪ Azoxystrobin (Quadris, Evito) ▪ Azoxystrobin + chlorothalonil (Quadris Opti) ▪ Azoxystrobin + difenoconazole (Quadris Top) ▪ Pyraclostrobin (Headline) ▪ Metconazole (Quash) ▪ Pyrimethanil (Scala) ▪ Fenamidone (Reason) ▪ Famoxadone + cymoxanil (Tanos) ▪ Cymoxanil (Curzate) ▪ Cyazofamid (Ranman) ▪ Zoxamide + chlorothalonil (Zing!) ▪ Zoxamide + mancozeb (Gavel) ▪ Dimethomorph (Forum) ▪ Propamocarb HCl (Previcur Flex) ▪ EBDCs (e.g., Dithane, Manzate) ▪ Chlorothalonil (e.g. Bravo ▪ Copper-based products (many) ▪ Tin products (Super Tin)	Early blight, white mold, late blight
	Desiccants (for growers practicing vine kill; some of these products can also provide weed control/suppression at vine-kill application timing): ▪ Carfentrazone-ethyl (Aim) ▪ Diquat (Reglone and others) ▪ Glufosinate-ammonium (Rely) ▪ Paraquat ▪ Pyraflufen-ethyl (Vida) ▪ Sulfuric acid	

Critical needs for pest management during row closure to harvest

Research topics

- Investigate timing of common pesticide treatments and residues to explore potential for reducing post-harvest intervals (PHIs) for certain products.
- Research effective insecticide modes of action for controlling potato insect pests including psyllid, thrips and Lygus; include activity against egg, larval and adult stages.
- Research tank mix compatibility and synergies or impacts of mixed products, including topics such as chemistry performance in tank mixes, inhibition of systemic effects, antagonism and potential for crop injury.
- Investigate market shifts in additives and surfactants and impacts to pesticide efficacy.
- Identify effective alternatives to pesticides in potato pest management, including nonchemical control for insects and diseases (biocontrol, other practices).
- Research new and effective technologies for pesticide application that maximize efficacy and minimize risks.
- Research the impact of late-season weeds.
- Investigate factors that impact stem end discoloration, and whether this is a pest-related issue or has other causes.
- Research using drones for better pest monitoring or targeted pesticide applications.
- Investigate varietal differences in pest susceptibility
- Research to develop guidelines for pollinator best practices, including insecticide avoidance during periods of high pollinator activity and selection of materials with low risk to pollinators if use is necessary during bloom.

Regulatory actions

- Clarify the importance of aerial application of certain pesticides due to limitations on ground applications in potato fields after row closure.
- Harmonize pesticide label formats so that categories of information are found in the same place on every pesticide label.
- Work with EPA and manufacturers to register insecticides for use in potato with shorter post-harvest intervals (PHIs).
- Communicate the importance of continued registration of existing products with short PHIs, including pyrethroids, which are important tools for late-season insect control, and fungicides for late season blight control.

Education

- Communicate with insecticide manufacturers regarding the need for insecticides with short PHIs.
- Educate growers and consultants on the use of package mixes (such as pyrethroids and neonicotinoids) and impacts to resistance management.

- Educate growers and consultants related to the use of additives and surfactants and potential impacts to pesticide efficacy.
- Educate growers and consultants on pesticide selection issues including best classes of chemistry for efficacy against certain pests, best timing of application for best efficacy and the existence of numerous products with different product names and formulations but same active ingredients.
- Develop a decision-support tool for potato pest management; Washington State University's tree fruit "Decision Aid System" offers a useful and successful model.
- Educate growers and consultants on how to understand labeling and supplemental labels for generic products.
- Educate growers and consultants on ways to optimize pesticide selection and compare products based on label language.
- Educate growers and consultants on interpretation and functionality of new and existing monitoring tools (spore trapping, psyllid distribution data, etc.)

Harvest to postharvest

Harvest begins as early as late June or as late as October, on a field-by-field basis, depending on location, cultivar and market class (fresh, processing, need for storage potatoes, etc.). However, weather and other end-user constraints can make it difficult to harvest even under optimal conditions.

The primary pest management challenge at harvest is minimizing damage to potatoes during harvest operations and removing diseased tubers before storage. Late blight, Fusarium dry rot, pink rot, Pythium leak, and soft rot are important diseases that can cause storage rot problems and that can be exacerbated by tuber damage during harvest and handling.

Two major components of managing potato quality in storage are sprout inhibition and disease suppression. If proper sprout control is not maintained, significant 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. Visible sprouts on fresh pack potatoes are not acceptable to consumers. The primary method to control sprouting in storage is use of chlorpropham (CIPC). CIPC inhibits sprout development by interfering with cell division.

The three basic tools of storage management—temperature, humidity, and airflow—help in managing many diseases in storage. Potatoes can be treated with a post-harvest fungicide or disinfestant as the potatoes are being loaded into the storage facility. Products are typically applied as a low-pressure and low-volume spray to the potatoes as they are conveyed into the storage facility. Only general biocides or disinfestants, such as chlorine dioxide, hydrogen peroxide, 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 can be applied through the humidification system, thermally applied, or by direct or gas application.

Field activities and pest management decisions that may occur during harvest to postharvest

- Digging to assess skin quality, disease presence and processing quality (if applicable)
- Water monitoring to achieve appropriate soil moisture for harvest
- Harvester and handling equipment adjustments
- Assessing proper pulp temperatures
- Desiccants (vine-kill)
- Harvest
- Prestorage fungicide or disinfestation treatment
- Storage
- Storage fogging or atmospheric treatments

PAMS practice	Harvest to post-harvest management activities	Target pest(s)
Prevention	Harvester adjustments to avoid bruising	Fusarium dry rot, Pythium leak, pink rot, soft rot
	Monitoring storage conditions including temperature, humidity and airflow	Silver scurf, leak, pink rot, late blight, soft rot, dry rot, other diseases and storage rots; pressure bruising
	Sorting potatoes to avoid introduction of infected tubers in storage	Late blight, pink rot, Pythium leak, bacterial soft rot
	Wound healing by airflow and gradual temperature decrease	General pathogen/disease management including soft rot bacteria; dry rot, pink rot, Pythium leak, pressure bruising; also minimizes weight loss
	Storage area cleaning and sanitation	Soft rot, silver scurf, ring rot
Avoidance	Timing harvest to limit insect and disease pressure	Tuberworm, psyllids, diseases
	Water management	Tuberworm, tuber rot, other diseases, bruise potential
	Monitoring internal temperature of tubers going into storage to keep cool	Storage rots: dry rot, Pythium leak, pink rot, soft rot
Monitoring	Monitoring disease levels in harvested crop	General disease management
Suppression	Post-harvest applications:	
	Phosphites	Pink rot, late blight, silver scurf
	Disinfestants ▪ Chlorine dioxide (through humidification system or gas) ▪ Peroxide/peroxyacetic acid (HPPA) solution (oxidizing disinfestants to prevent pathogen contamination of drench solutions	Late blight, Fusarium dry rot, pink rot, Pythium leak, soft rot, silver scurf
	Fludioxonil + azoxystrobin +_ difenoconazole (Stadium)	Late blight, Fusarium dry rot, silver scurf
	Sprout inhibitors: CIPC, 1,4DMN, or “Smart Block” type products to inhibit sprouts/buds on potatoes to make them suitable for the fresh market	

Critical needs for pest management during harvest to post harvest

Research topics

- Investigate the efficacy of the various postharvest and storage treatments, including disinfestants
- Research the impacts of storage on disease development (for example, whether disease development increases under storage conditions).
- Determine the impacts of storage conditions on newly released potato varieties.
- Develop methods for early detection of decay in storage.

- Investigate factors that impact stem end discoloration and whether this is pest-related or has other causes.
- Support development of new or alternative sprout inhibitors to CIPC.
- Determine the efficacy of desiccants on late-season weeds.

Regulatory actions

- Work with USDA Foreign Agricultural Service, registrants, and other regulatory agencies to improve the definition of certain post-harvest fungicides in regulatory systems that define these as food additives, which results in rejections from certain markets.

Education

- Educate growers on proper pest identification for problematic storage insects and diseases.

Invasive and emerging pests

Insects and mites

None at this time.

Weeds

The development of weed resistance to commonly used herbicides is increasing. This is an area that needs more support, research and tracking.

Diseases

Tobacco rattle virus, potato mop top virus, and tuber necrotic PVY strains (PVY^{NTN}) should be investigated for potential to infect Pacific Northwest potatoes, potential damage and treatment.

Critical needs for invasive and emerging pests

Research topics

- Research and tracking of weed resistance to commonly used herbicides in potato.
- Research and tracking of emerging diseases.

Regulatory actions

None at this time

Education

None at this time

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Appendices

Activity table for potato: Treasure Valley

Field activities (other than pest management)

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Dry fertilizer application including manure/compost	X	X	X	X	X	X	X				X	X
Fall bedding											X	X
Harvest								X	X	X		
Hilling—“Dammer Diking”				X	X							
Irrigation				X	X	X	X	X	X			
Liquid fertilizer (fertigation)					X	X	X					
Petiole/soil sampling					X	X	X					
Planting				X	X							
Row markout										X	X	
Seed cutting			X	X								
Seed delivery			X	X								
Seed purchase	X	X	X								X	X
Soil sampling for nutrients		X	X	X	X						X	X
Tillage/field preparation		X	X	X						X	X	
Vinekill (desiccation)								X	X			

Pest management activities

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Chop/incorporate biofumigant or green manure										X	X	
Cull pile management	X	X	X	X	X	X	X	X	X	X	X	X
Foliar fungicide application					X	X	X	X	X			
Foliar insecticide application						X	X	X				
Fumigation		X	X						X	X	X	
Herbicide applications				X	X							
In-furrow pesticide applications at planting			X	X	X							
Nematode chemigation						X	X	X	X			
Plant biofumigant (previous year)								X				
Postharvest pesticide applications (fungicides, biocides)								X	X	X		
Seed treatment			X	X								
Soil sampling for nematodes								X	X	X	X	
Volunteer potato control					X	X	X					

Seasonal pest management for potato: Treasure Valley

Notes:

X = times when pest-management strategies are applied to control these pests, not all times when pest is present. Storage diseases such as soft rot, pink rot, etc. require management throughout the storage season (airflow, monitoring, etc.) which is not reflected in this table.

Insects and nematodes	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Aphid/PVY and PLRV			X	X	X		X	X				
Beet leafhopper/ phytoplasma/purple top												
Colorado potato beetle			X	X	X							
Caterpillars (cutworm, armyworm, looper)						X	X	X				
Flea beetle												
Lygus bug/stink bug							X	X				
Psyllid/Liberibacter/zebra chip				X	X	X	X	X	X			
Slug												
Spider mite							X	X				
Thrips							X	X				
Tuberworm												
Wireworm			X	X								
Diseases and viruses	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
White mold (Sclerotinia stem rot)					X	X	X					
Early blight and brown spot					X	X	X	X	X			
Fusarium dry rot (includes storage applications)			X	X					X	X		
Late blight (includes storage applications)			X	X	X	X	X	X	X	X		
Pythium leak + pink rot (includes storage applications)				X	X	X	X		X	X		
Nematodes: root knot, root lesion, stubby root			X	X	X	X	X	X		X	X	
Rhizoctonia canker (black scurf)			X	X	X							
Ring rot			X	X								
Bacterial soft rot			X	X	X							
Blackleg (managed through seed selection)			X	X								
Lenticel rot (managed through proper irrigation)						X	X	X	X			

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Silver scurf				X	X				X	X		
Stubby root nematode/TRV/ corky ringspot			X	X	X	X	X	X		X	X	
Verticillium Wilt (Potato Early Dying) + black dot (includes water management to reduce susceptibility)		X	X			X	X	X	X	X	X	
Weeds	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Annual broadleaves			X	X	X							
Perennial broadleaves			X	X	X					X	X	
Annual Grasses			X	X	X							
Perennial Grasses			X	X	X					X	X	

Activity table for potato: East Idaho

Field Activities (other than pest management)

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Dry fertilizer application including manure/compost				X	X							
Harvest								X	X	X		
Hilling, “Dammer Diking”				X	X							
Irrigation					X	X	X	X	X			
Liquid fertilizer (fertigation)						X	X					
Petiole/soil Sampling						X	X	X				
Planting				X	X							
Seed cutting			X	X	X							
Seed purchase			X	X								
Soil sampling for nutrients			X	X	X					X	X	
Tillage/field preparation			X	X	X					X	X	

Pest Management Activities

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Chop/incorporate biofumigant or green manure										X		
Cull pile management	X	X	X	X	X	X	X	X	X	X	X	X
Field scouting					X	X	X	X	X			
Foliar fungicide applications						X	X	X	X			
Foliar insecticide applications							X	X				
Fumigation									X	X	X	
Herbicide applications					X	X						
In-furrow applications at planting				X	X							
Nematode chemigation						X	X	X				
Plant biofumigant (previous year)								X				
Postharvest pesticide applications (fungicides, biocides)									X	X		

Seed treatment			X	X	X							
Soil sampling for nematodes								X	X			
Storage management	X	X	X	X	X	X	X	X	X	X	X	X
Volunteer potato control					X	X	X					

Seasonal pest management for potato: East Idaho

Notes:

X = times when pest-management strategies are applied to control these pests, not all times when pest is present. Storage diseases such as soft rot, pink rot, etc. require management throughout the storage season (airflow, monitoring, etc.) which is not reflected in this table.

Insects and nematodes	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Aphid/PVY and PLRV				X	X			X				
Beet leafhopper/ phytoplasma/ purple top												
Colorado potato beetle				X	X							
Caterpillars (cutworm, armyworm, looper)								X				
Flea beetle												
Lygus bug/stink bug												
Psyllid/Liberibacter/zebra chip							X	X				
Slug												
Spider mite												
Thrips												
Tuberworm												
Wireworm				X	X							
Diseases and viruses	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Downy mildew + white mold (Sclerotinia stem rot)						X	X					
Early blight and brown spot						X	X	X				
Fusarium dry rot				X	X							
Late blight					X	X	X	X				
Pythium leak + pink rot				X	X	X		X	X			
Nematodes: root knot, root lesion, stubby root			X	X	X	X	X			X	X	
Rhizoctonia canker (black scurf)				X	X							
Ring rot				X	X							
Bacterial soft rot				X	X							
Blackleg				X	X							
Lenticel rot								X	X			
Common scab			X		X	X						

Silver scurf				X	X				X	X		
Stubby root nematode/ TRV/corky ringspot				X	X	X	X			X	X	
Spongospora/Powdery scab/Potato mop-top virus												
Verticillium Wilt (Potato Early Dying) + black dot										X	X	
Black Dot						X						
Weeds	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Annual broadleaves					X							
Perennial broadleaves					X							
Annual Grasses					X							
Perennial Grasses					X							

Activity table for potato: Klamath Basin

Field activities (other than pest management)

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Dry fertilizer application including manure/compost				X	X	X						
Green manure planting (previous year)							X	X				
Harvest								X	X	X		
Hilling –“Dammer Diking”					X	X						
Irrigation					X	X	X	X	X	X		
Liquid fertilizer (fertigation)						X	X	X				
Manure/compost application			X							X	X	
Petiole/soil sampling						X	X	X				
Planting				X	X	X						
Row markout				X	X					X		
Seed cutting				X	X							
Seed purchase			X	X								
Soil sampling for nutrients			X	X				X	X			
Tillage/field preparation			X	X						X	X	
Vinekill (desiccation)								X	X			

Pest management activities

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Fumigation				X	X				X	X		
Seed treatment				X	X							
In-furrow applications at planting				X	X	X						
Herbicide applications					X	X						
Foliar fungicide applications						X	X	X	X			
Foliar insecticide applications					X	X	X	X	X			
Nematode chemigation						X	X	X				

Soil sampling for nematodes								X	X			
Cull pile management	X	X	X	X	X	X	X	X	X	X	X	X
Volunteer potato control					X	X	X					
Field scouting					X	X	X	X	X			
Storage management	X	X	X	X	X	X	X	X	X	X	X	X

Seasonal pest management for potato: Klamath Basin

Notes:

X = times when pest-management strategies are applied to control these pests, not all times when pest is present. Storage diseases such as soft rot, pink rot, etc. require management throughout the storage season (air flow, monitoring, etc.) which is not reflected in this table.

Insects and nematodes	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Aphid/PVY and PLRV				X	X	X	X	X				
Beet leafhopper/ phytoplasma/ purple top												
Colorado potato beetle												
Caterpillars (cutworm, armyworm, looper)							X	X				
Flea beetle					X	X						
Lygus bug/stink bug												
Psyllid/Liberibacter/zebra chip							X	X				
Slug												
Spider mite												
Thrips												
Tuberworm												
Wireworm				X	X							
Diseases and viruses	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
White mold							X	X				
Downy mildew + (Sclerotinia stem rot) + early blight and brown spot						X	X	X				
Fusarium dry rot					X							
Late blight							X	X	X			
Pythium leak + pink rot						X	X		X	X		
Nematodes: root knot, root lesion, stubby root				X	X	X	X	X	X	X		
Rhizoctonia canker (black scurf)				X	X	X						
Ring rot				X	X							
Bacterial soft rot			X	X				X	X	X		
Lenticel rot												
Blackleg				X	X							

Common scab												
Silver scurf				X	X	X						
Stubby root nematode/TRV/ corky ringspot				X	X	X	X	X	X	X		
Spongospora/powdery scab/ Potato mop-top virus												
Verticillium wilt (Potato early dying) + black dot				X					X	X		
Black Dot						X	X					
Weeds	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Annual broadleaves					X	X	X					
Perennial broadleaves												
Annual grasses												
Perennial grasses												

Activity table for potato: Magic Valley

Field activities (other than pest management)

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Dry fertilizer application including maure/compost			X	X	X						X	X
Harvest								X	X	X		
Hilling – "Dammer Diking"				X	X							
Irrigation					X	X	X	X	X			
Liquid fertilizer (fertigation)						X	X	X				
Petiole sampling						X	X	X				
Planting			X	X	X							
Row markout											X	X
Seed cutting			X	X	X							
Seed purchase		X	X	X								
Soil sampling for nutrients			X	X	X						X	
Tillage/field preparation			X	X						X	X	
Vinekill (desiccation)								X	X			

Pest management activities

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Cull pile management	X	X	X	X	X	X	X	X	X	X	X	X
Field scouting					X	X	X	X	X			
Foliar fungicide applications						X	X	X	X			
Foliar insecticide applications						X	X	X				
Fumigation			X						X	X	X	
Herbicide applications				X	X	X						
In-furrow applications at planting				X	X							
Nematode chemigation						X	X	X				

Postharvest pesticide applications (fungicides, biocides)								X	X	X		
Seed treatment				X	X							
Soil sample for nematodes								X	X			
Storage management	X	X	X	X	X	X	X	X	X	X	X	X
Volunteer potato control					X	X	X					

Seasonal pest management for potato: Magic Valley

Notes:

X = times when pest-management strategies are applied to control these pests, not all times when pest is present. Storage diseases such as soft rot, pink rot, etc. require management throughout the storage season (airflow, monitoring, etc.) which is not reflected in this table.

Insects and nematodes	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Aphid/PVY and PLRV				X	X			X				
Beet leafhopper/ phytoplasma/ purple top												
Colorado potato beetle				X	X							
Caterpillars (cutworm, armyworm, looper)								X				
Flea beetle												
Lygus bug/stink bug												
Psyllid/Liberibacter/zebra chip				X	X	X	X	X				
Slug												
Spider mite							X					
Thrips												
Tuberworm												
Wireworm				X	X							
Diseases and viruses	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
White mold						X	X					
Early blight and brown spot						X	X	X	X			
Fusarium dry rot				X	X				X	X		
Late blight				X	X	X	X	X	X			
Pythium leak + pink rot				X	X	X	X	X	X	X		
Nematodes: root knot, root lesion, stubby root			X	X	X	X	X			X	X	
Rhizoctonia canker (black scurf)				X	X							
Ring rot				X	X							
Bacterial soft rot				X	X			X	X	X		
Lenticel rot								X	X			
Blackleg				X	X							

Common scab				X	X	X						
Silver scurf				X	X			X	X	X		
Stubby root nematode/TRV/ corky ringspot				X	X	X	X			X	X	
Spongospora/powdery scab/ potato mop-top virus				X	X	X						
Verticillium wilt (potato early dying) + black dot										X	X	
Black Dot						X	X					
Weeds	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Annual broadleaves					X							
Perennial broadleaves					X							
Annual grasses					X							
Perennial grasses					X							

Activity table for potato: Columbia Basin

Field activities (other than pest management)

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Dry fertilizer application including manure/compost		X	X	X	X	X	X	?		X	X	
Fall bedding?												
Harvest						X	X	X	X	X		
Hilling – “Dammer Diking”												
Irrigation			X	X	X	X	X	X	X	X		
Liquid fertilizer (fertigation)						X	X	X				
Petiole sampling					X	X	X	X				
Plant/harvest green manure							X	X	X	X	X	
Planting		X	X	X	X							
Seed cutting												
Seed delivery												
Seed purchase	X	X	X	X					**X**	**X**	**X**	**X**
Soil sampling for nutrients		X	X	X	X	X	X	X	X	X		
Tillage/field preparation		X	X	X	X				X	X	X	
Vinekill (desiccation)?												

Pest management activities

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Cull pile management	X	X	X	X	X	X	X	X	X	X	X	X
Field scouting			X	X	X	X	X	X	X	X		
Foliar fungicide applications			X	X	X	X	X	X	X	X		
Foliar insecticide applications			X	X	X	X	X	X	X			
Fumigation		X	X					X	X	X	X	
Herbicide applications			X	X	X	X						

In-furrow applications at planting												
Nematode chemigation												
Postharvest pesticide applications (fungicides, biocides)												
Seed treatment												
Soil sampling for nematodes												
Storage management	X	X	X	X	X	X	X	X	X	X	X	X
Volunteer potato control			X	X	X	X	X					

Seasonal pest management for potato: Columbia Basin

Notes:

X = times when pest-management strategies are applied to control these pests, not all times when pest is present. Storage diseases such as soft rot, pink rot, etc. require management throughout the storage season (air flow, monitoring, etc.) which is not reflected in this table.

Insects and nematodes	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Aphid/PVY and PLRV			X	X	X	X	X	X	X			
Beet leafhopper/ phytoplasma/ purple top			X	X	X	X	X					
Colorado potato beetle			X	X	X	X	X	X	X			
Caterpillars (cutworm, armyworm, looper)						X	X					
Flea beetle												
Lygus bug/stink bug					X	X	X	X				
Psyllid/Liberibacter/zebra chip			X	X	X	X	X	X	X			
Slug												
Spider mite							X	X				
Thrips						X	X	X				
Tuberworm								X	X	X		
Wireworm		X	X	X	X				X	X	X	
Diseases and viruses	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Downy mildew + white mold (Sclerotinia stem rot) + Early blight and brown spot (*Alternaria* spp.)					X	X	X	X				
Fusarium dry rot			X	X	X							
Late blight			X	X	X	X	X	X	X	X		
Pythium leak + pink rot			X	X	X	X	X	X	X	X		
Nematodes: root knot, root lesion, stubby root		X	X	X	X	X	X	X	X	X	X	
Rhizoctonia canker (black scurf)			X	X	X							
Ring rot		X	X									

Other rots: bacterial soft rot, blackleg, and lenticel rot			X	X								
Common scab		X							X	X	X	
Silver scurf			X	X	X				X	X		
Stubby root nematode/TRV/ corky ringspot		X	X	X	X	X	X	X	X	X	X	
Spongospora/powdery scab/ Potato mop-top virus												
Verticillium wilt (potato early dying) + black dot			X	X	X	X	X	X	X	X	X	
Weeds	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Annual broadleaves		X	X	X	X	X						
Perennial broadleaves		X	X	X	X	X						
Annual grasses			X	X	X	X			X	X		
Perennial grasses			X	X	X	X			X	X		

Activity tables for potato: west of Cascades/NW Washington

Field activities (other than pest management)

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Clean equipment			X	X	X							
Clean storage buildings								X	X			
Fertilizing (dry/liquid)					X	X	X	X				
Harvest									X	X		
Irrigation						X	X					
Maintain field drainage	**X**	**X**	**X**	**X**	**X**							
Planting					X	X						
Post-emergence tillage/Dammer-Diking												
Seed delivery												
Seed purchase												
Skin color enhancement (2,4,D)							X					
Sprout inhibition (MH-30)							X					
Storage	X	X	X								X	X
Tillage/field preparation				X	X					X	X	
Vinekill (desiccation)								X	X			
Seed cutting												

Pest management activities

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Cultivation (weeds)				X	X							
Field Scouting					X	X	X	X	X			
Foliar fungicide applications					X	X	X	X				
Foliar insecticide applications						X	X	X				

Fumigation												
Herbicide applications					X	X	X					
In-furrow applications at planting					X	X						
Postharvest pesticide applications (fungicides, biocides)									X	X		
Seed treatment				X	X	X						
Seed treatment												
Soil sampling for nematodes												
Storage management	X	X	X	X	X	X	X	X	X	X	X	X

Seasonal pest management for potato: west of Cascades/NW Washington

Notes:
X = times when pest-management strategies are applied to control these pests, not all times when pest is present.
Storage diseases such as soft rot, pink rot, etc. require management throughout the storage season (airflow, monitoring, etc.) which is not reflected in this table.

Insects and nematodes	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Aphid/PVY and PLRV						X	X	X				
Beet leafhopper/ phytoplasma/ purple top												
Colorado potato beetle												
Caterpillars (cutworm, armyworm, looper)												
Flea beetle						X	X					
Lygus bug/stink bug												
Psyllid/Liberibacter/zebra chip												
Slug					X	X	X	X				
Spider mite												
Thrips												
Tuberworm												
Wireworm					X	X						
Diseases and viruses	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Downy mildew + white mold (Sclerotinia stem rot) + Early blight and brown spot (*Alternaria* spp.)							X	X				
Fusarium dry rot					X	X						
Late blight				X	X	X	X	X				
Pythium leak + Pink rot												
Nematodes: Root knot, root lesion, stubby root												

Rhizoctonia canker (black scurf)				X	X	X						
Ring rot												
Common scab					X	X						
Silver scurf					X	X			X	X		
Stubby root nematode/TRV/ corky ringspot												
Spongospora/powdery scab/ Potato mop-top virus												
Verticillium Wilt (Potato Early Ddying) + black dot												
Weeds	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Annual broadleaves			X	X	X	X	X					
Perennial broadleaves			X	X	X	X	X					
Annual grasses			X	X	X	X	X					
Perennial grasses			X	X	X	X	X					

Potato pesticide risk management

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

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

Any product highlighted in yellow is classified as a "highly hazardous pesticide" (HHP) by the World Health Organization and the Food and Agriculture Organization of the United Nations. These products may pose significant risks to human health or the environment, and risk reduction measures may not be effective in mitigating these risks.

Pesticides	Risks requiring mitigation	Preplant	Planting to pre-emergence	Emergence to row closure	Row closure to vine kill	Harvest to postharvest	Target pests	Comments
Insecticides	**When used, average number of applications per crop stage**							
Abamectin (Agri-mek, Reaper)	A,P				1-3			
Acetamiprid (Assail 30SG, Intruder Max 70WP)	A							Not used
Bifenazate (Acramite)	-				1-2			
Bifenthrin (Tundra EC, Fanfare 2EC)	A,P			0-1	1-2			0-1 at emergence in Idaho
Carbaryl (Sevin)	A,P,T							Not used
Chlorantraniliprole (Coragen)	-				0-1			Not used in ID (too expensive)
Clothianidin (Belay)	A,P		0-1		0-1			Can be used as seed treatment
Cyantraniliprole (Verimark)	ND				0-1			New, not used yet
Cyfluthrin (Renounce)				0-1	1-2			
Beta-cyfluthrin (Baythroid)				0-1	1-2			
Lambda-cyhalothrin (Warrior, Province)	A,P			0-1	1-2			

Pesticides	Risks requiring mitigation	Preplant	Planting to pre-emergence	Emergence to row closure	Row closure to vine kill	Harvest to postharvest	Target pests	Comments
Gamma-cypermethrin (Respect, Mustang)	A			0-1	1-2			
Cyromazine (Trigard)	-							Not used
Deltamethrin (Battalion)	A,P			0-1	1-2			
Dimethoate (various brands)	A,T,P,B			0-1	1-2			
Dinotefuran (Scorpion, Venom)	A,P			0-1				West of cascades
Esfenvalerate (Asana, Adjorn)	A,P			0-1	1-2			
Ethoprop (Mocap)		0-1	0-1				nematodes	suppression
Fipronil (Regent)	-	0-1	0-1					
Flonicamid (Beleaf)	-			0-2				
Hexythiazox (Onager)	-				0-2			
Imidacloprid (many brands)	A,P		1	0-1	0-2			
Indoxacarb (Avaunt)	P			0-1				
Malathion (many brands)	P							Not used
Methomyl (Lannate)					2-3			Not used in ID
Novaluron (Rimon)	A			0-2				
Oxamyl (Vydate)			0-1	2-4	2-5			8 total max applications
Permethrin (many brands)	A,T,P			0-1	1-2			
Phorate (Thimet, Phorate)								Not used
Phosmet (Imidan)	A,T,B							Not used
Propargite (Comite)	T				1-2			
Pymetrozine (Fulfill)	-				0-2			
Spinetoram (Radiant)	P			0-1				
Spinosad (Success, Entrust)	P			0-1	1-2			
Spiromesifen (Oberon)	-			0-2	0-2			
Spirotetramat (Movento)	-				2			
Sulfoxaflor (Transform)	-			0-2				

Pesticides	Risks requiring mitigation	Preplant	Planting to pre-emergence	Emergence to row closure	Row closure to vine kill	Harvest to postharvest	Target pests	Comments
Thiamethoxam (Actara, Cruiser, Platnum)	A,P		0-1	0-1	0-1			
Tolfenpyrad (Torac)	A			1-2	1-2			
Fungicides		**When used, average number of applications per crop stage**						
Ametoctradin + Dimethomorph (Zampro)	Ametoctradin ND Dimethomorph -				0		Late blight	Could be used for late blight; rarely used due to cost
Azoxystrobin (Quadris)	A	1	1	1	1		Black dot, early blight, silver scurf, Rhizoctonia	Would not be used at every timing, usually applied once
Azoxystrobin + Benzovindiflupyr (Elatus)	Azoxystrobin A Benzovindiflupyr ND		1				Rhizoctonia, silver scurf	
Boscalid (Endura)	-			1	1-2		Early blight, white mold	
Chlorothalonil (Bravo, Echo)	A,T			1	2-4		Early blight, late blight	
Clarified Hydrophobic Extract of Neem Oil (Trilogy)	-							Not used
Copper 8-Quinolinolate	-						Bacterial vine rot	Not used
Copper diammonia diacetate complex (Liqui-cop)	-						Bacterial vine rot	Used by organic growers
Copper hydroxide (Champ)	T			1	2		Bacterial vine rot, early blight	
Copper Octanoate (Cueva)	-			1	2		Bacterial vine rot	
Copper oxychloride + copper sulfate (C-O-C-S WDG)	-			1	2		Bacterial vine rot	
Copper sulfate (Bordeaux 8-8-100)	-			1	2		Bacterial vine rot	

Pesticides	Risks requiring mitigation	Preplant	Planting to pre-emergence	Emergence to row closure	Row closure to vine kill	Harvest to postharvest	Target pests	Comments
Cyazofamid (Ranman)	-		1		2		Pink rot, late blight	Used for pink rot, planting to pre emergence; used for late blight, if present, from row closure to vine kill
Cymoxanil (Curzate 60DF)	-				1		Used for late blight, if present	
Cymoxanil + Famoxadone (Tanos)	A, T			1	1		Early blight, late blight	
Dicloran (Botran 5F)	T,B							Not used
Dimethomorph (Forum)	-				1			For late blight control, if present
Fenamidone (Reason)	-							Not used
Fluazinam (Omega)	B			1	1			White mold control, late blight if present
Fludioxonil + Mancozeb (Maxim MZ)	T		1				Rhizoctonia, Dry rot, silver scurf	Seed treatment
Fluopyram (Velum Prime)	T		1				Nematodes, early blight, white mold	
Fluopyram + pyrimethanil (Luna Tranquility)	T			1	1		Early blight, white mold	
Fluoxastrobin (Aftershock, Evito)	-		1	1			Rhizoctonia, black dot	
Flutolanil (Moncut 70DF)	-		1				Rhizoctonia	
Iprodione (Nevado)	-		1	1			White mold	Not used much
Mancozeb (Dithane Rainshield)	T			1	3-4		Early blight, late blight	
Mandipropamid (Revus)	-		1		1		Late blight	Seed treatment or foliar
Mandipropamid + difenoconazole (Revus Top)	-				1		Early blight, late blight	
Mefenoxam (Ridomil)	-		1	2			Leak, pink rot	In furrow or foliar

Pesticides	Risks requiring mitigation	Preplant	Planting to pre-emergence	Emergence to row closure	Row closure to vine kill	Harvest to postharvest	Target pests	Comments
Metalaxyl (MetaStar)	T		1	2			Leak, pink rot	In furrow or foliar
Metconazole (Quash)	T			1	1		Early blight, white mold	
Metiram (Polyram)	T,B				1		Early blight, late blight	
Mono- and dibasic sodium, potassium, and ammonium phosphites (Alude)	ND							Brand not used
Mono-and dipotassium salts of Phosphorous Acid (Fosphite)	-			2	1	1	Pink rot, late blight	Rarely used
Oxathiapiprolin (Orondis)	ND		1		2		Pink rot, late blight	
Potassium bicarbonate (MilStop)	-							Not used
Paraffinic oil (JMS Stylet Oil)	ND							Not used
Pentachloronitrobenzene (Blocker 4)	ND		1	1			Rhizoctonia, black dot	Rhizoctonia – in furrow; Black Dot applied to 8” plants
Penthiopyrad (Vertisan)	ND		1		1		Rhizoctonia, early blight	
Phosphorous Acid (Agri-Fos)	-			2	1	1	Pink rot, Late blight	Rarely used
Polyoxin D zinc salt (OSO)	-							Not used
Propamocarb hydrochloride (Previcur Flex)	P				1		late blight	If present
Pyraclostrobin (Headline)	A		1	1			Rhizoctonia, early blight, black dot	
Pyrimethanil (Scala SC)	-				1			Rarely used
Pyrimethanil + Trifloxystrobin (Distinguish 480)	A							Not used

Pesticides	Risks requiring mitigation	Preplant	Planting to pre-emergence	Emergence to row closure	Row closure to vine kill	Harvest to postharvest	Target pests	Comments
Sodium hypochlorite	A					1	Bacterial diseases	
Streptomycin Sulfate (Firewall)	-							Not used
Sulfur (Microthiol Disperss; Kumulus DF))	-			1	2		Bacterial disease, powdery mildew	
Thiabendazole (Mertect 340)	A,T,P							Not used
Thiophanate-methyl (Topsin M WSB)	T			1	1		White mold	Rarely used
Trifloxystrobin (Gem)	A							Not used
Triphenyltin Hydroxide (Super Tin 80 WP)	ND				1-2		Late blight, early blight	Rarely used
Quaternary ammonium compounds	ND		1	1			Ring rot, dry rot	Sanitation, used to clean storage and equipment
Herbicides	**When used, average number of applications per crop stage**							
Dimethenamid-P (Outlook)	-	1					Broadleaf weeds	No use post emergence
EPTC (Eptam)	T,P,B		1	1-2				
Flumioxazin (Chateau)			1					Not widely used
Fomesafen (Reflex)	B							Not widely used
Metribuzin (TriCor DF 75% and others)	T		1	1-2				
Metolachlor (Stalwart or others)	T		1					
S-metolachlor (Dual Magnum)	A		1					
Paraquat (Gramoxone SL, Inteon, Firestorm)	T				1			Can be used as a desiccant
Pendimethalin (Prowl 3.3 or H2O)	T		1					
Ethalfluralin (Sonalan HFP)	A		1	1				
Trifluralin (Treflan or others)	T		1	1				

Pesticides	Risks requiring mitigation	Preplant	Planting to pre-emergence	Emergence to row closure	Row closure to vine kill	Harvest to postharvest	Target pests	Comments
Rimsulfuron (Matrix or others) postemergence	-		1	1				
Clethodim (Select)	-			1				Used early row closure
Sethoxydim (Poast Plus)	-							Not registered in WA
Soil fumigants	**When used, average number of applications per crop stage**							
1,3-Dichloropropene (Telone II)	A,T,P,B	1					Nematodes	
Metam sodium (Sectagon, Vapam HL)	A,T	1					Verticillium, root lesion nematodes	
1,3-Dichloropropene + Chloropicrin (Telone C-17)	A,T,P,B	1					Nematodes, Verticillium, scab	
Metam potassium	A,T	1					Verticillium, root lesion nematodes	

Efficacy ratings for PATHOGEN and NEMATODE management tools in potato

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

Management tools	Downy mildew + white mold	Early blight and brown spot (Alternaria spp.)	Fusarium dry rot	Late blight	Pythium leak + pink rot	Nematodes: Root knot, root lesion, stubby root	Rhizoctonia canker (black scurf)	Ring rot	Rots: bacterial soft rot, blackleg and lenticel rot	Common scab	Silver scurf	Stubby root nematode/TRV/corky ringspot	Spongospora/Powdery scab/Potato mop-top Virus	Verticillium wilt (Potato early dying) + black dot	Comments
Registered chemistries															
Ametoctradin + Dimethomorph (Zampro)				E											
Azoxystrobin (Quadris)		P		P			G				F				Resistance present in *A. solani* and *A. alternata* populations.
Azoxystrobin + Benzovindiflupyr (Elatus)							G				F				
Boscalid (Endura)	E	P-F													Resistance present in *A. solani*
Chlorothalonil (Bravo, Echo)		F		F-G											
Copper 8-Quinolinolate															
Copper diammonia diacetate complex (Liqui-cop)															
Copper hydroxide (Champ)		P		P					P						
Copper Octanoate (Cueva)		P		P					P						

Management tools	Downy mildew + white mold	Early blight and brown spot (Alternaria spp.)	Fusarium dry rot	Late blight	Pythium leak + pink rot	Nematodes: Root knot, root lesion, stubby root	Rhizoctonia canker (black scurf)	Ring rot	Rots: bacterial soft rot, blackleg and lenticel rot	Common scab	Silver scurf	Stubby root nematode/TRV/corky ringspot	Spongospora/Powdery scab/Potato mop-top Virus	Verticillium wilt (Potato early dying) + black dot	Comments
Copper oxychloride + copper sulfate (C-O-C-S WDG)		P		P					P						
Copper sulfate (Bordeaux 8-8-100)		P		P					P						
Cyazofamid (Ranman)				E	P										
Cymoxanil (Curzate 60DF)				G											
Cymoxanil + Famoxadone (Tanos)		P		F-G					P						Fungicide resistance with *A. solani*
Dicloran (Botran 5F)	P														
Dimethomorph (Forum)				F											
Ethoprop (Mocap)						F						F			
Fenamidone (Reason)		P		F											
Fluazinam (Omega)	G			G									P		
Fludioxonil + Mancozeb (Maxim MZ)			E	G			G				F				
Fluopyram (Velum Prime)	G					F						F			
Fluopyram + pyrimethanil (Luna Tranquility)	E	E													
Fluoxastrobin (Aftershock, Evito)		P		F										P	Resistance in *A. solani* and *A. alternata*
Flutolanil (Moncut 70DF)							G								
Iprodione (Nevado)	P	P													

Management tools	Downy mildew + white mold	Early blight and brown spot (Alternaria spp.)	Fusarium dry rot	Late blight	Pythium leak + pink rot	Nematodes: Root knot, root lesion, stubby root	Rhizoctonia canker (black scurf)	Ring rot	Rots: bacterial soft rot, blackleg and lenticel rot	Common scab	Silver scurf	Stubby root nematode/TRV/corky ringspot	Spongospora/Powdery scab/Potato mop-top Virus	Verticillium wilt (Potato early dying) + black dot	Comments
Kumulus DF		P		P						P					
Mancozeb (Dithane Rainshield)		F		F-G											
Mandipropamid (Revus)				E											
Mefenoxam (Ridomil)				(E)	G										Depends on Strain
Metalaxyl (MetaStar)				(E)	G										Depends on strain
Metiram (Polyram)		F		F-G											
Mono- and dibasic sodium, Potassium and Ammonium Phosphites (Alude)				E	F										E = Post Harvest, E for pink rot post-harvest
Mono-and dipotassium salts of Phosphorous Acid (Fosphite)				E	F										E = Post Harvest, E for pink rot post-harvest.
Oxamyl (Vydate)						G						G			
Oxathiapiprolin (Orondis)				E	F										
Potassium bicarbonate (MilStop)											P				
Paraffinic oil (JMS Stylet Oil)															Not used
Pentachloronitrobenzene (Blocker 4)							P			P					P for black dot
Penthiopyrad (Vertisan)		F-G					G							P	P for black dot

Management tools	Downy mildew + white mold	Early blight and brown spot (Alternaria spp.)	Fusarium dry rot	Late blight	Pythium leak + pink rot	Nematodes: Root knot, root lesion, stubby root	Rhizoctonia canker (black scurf)	Ring rot	Rots: bacterial soft rot, blackleg and lenticel rot	Common scab	Silver scurf	Stubby root nematode/TRV/corky ringspot	Spongospora/Powdery scab/Potato mop-top Virus	Verticillium wilt (Potato early dying) + black dot	Comments
Phosphorous Acid (Agri-Fos)				E	F						G				Efficacy rated for application to tubers; E rating is for pink rot, P for Pythium
Polyoxin D zinc salt (OSO)		P													
Propamocarb hydrochloride (Previcur Flex)				F											
Pyraclostrobin (Headline)		P												**F**	F for Black Dot, resistance in *A. solani* and *A. alternata*
Pyrimethanil (Scala SC)		F													F for gray mold
Sodium Hypochlorite								E	P						E for disinfesting equipment
Streptomycin Sulfate (Firewall)															Not used
Sulfur (Microthiol Disperss)	P								P						
Thiabendazole (Mertect 340)			P								P				Due to resistance
Thiophanate-Methyl (Topsin M WSB)	P														
Thiophanate-Methyl + Mancozeb (Evolve Potato Seed Piece Treatment)															Not used

Management tools	Downy mildew + white mold	Early blight and brown spot (Alternaria spp.)	Fusarium dry rot	Late blight	Pythium leak + pink rot	Nematodes: Root knot, root lesion, stubby root	Rhizoctonia canker (black scurf)	Ring rot	Rots: bacterial soft rot, blackleg and lenticel rot	Common scab	Silver scurf	Stubby root nematode/TRV/corky ringspot	Spongospora/Powdery scab/Potato mop-top Virus	Verticillium wilt (Potato early dying) + black dot	Comments
Trifloxystrobin (Gem)															Not used
Triphenyltin Hydroxide (Super Tin 80 WP)		F		G											
Quaternary Ammonium Compounds			E					E	E						Cleaning Equipment
Fumigants															
1, 3 Dichloropropene (Telone II)						E						G			
Dichloropropene + Chloropicrin						E				P		G		P	
Metam potassium						F								G	
Metam sodium (Sectagon, Vapam HL)						F								G	
Unregistered/New chemistries															
Metconazole (Quash)	G	G													
Pydiflumetofen + fludioxonil (Miravis Prime)	P	E													
Mefentrifluconazole (Provysol)	P	E													
Cultural/nonchemical strategies															
Biofumigant mustard, radish						F-G									

APPENDIX E

Efficacy ratings for INSECT management tools in potato

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

Management tools	Aphid/PVY and PLRV	Beet leafhopper/ phytoplasma/ purple top	Colorado potato beetle	Caterpillars (cutworm, armyworm, looper)	Flea beetle	Lygus bug/stink bug	Psyllid/Liberibacter/zebra chip	Slug	Spider mite	Thrips	Tuberworm	Wireworm	Comments
Abamectin (Agri-Mek, Reaper)			G				E		F/G	F			
Acetamiprid (Assail 30SG, Intruder Max 70WP)													Not used
Bifenazate (Acramite)							G		G/E				
Bifenthrin (Tundra EC, Fanfare 2EC)		G/E	G/E	F		F					E		Can flare secondary pests
Carbaryl (Sevin)													Not used
Chlorantraniliprole (Coragen)			E	E			G						Expensive
Clothianidin (Belay)	E		E				E						
Cyantraniliprole (Verimark)	E		G	F						G			
Cyfluthrin (Renounce)							G		G/E				Flares aphids and mites
Beta-Cyfluthrin (Baythroid)							G		G/E				Flares aphids and mites
Lambda-Cyhalothrin (Warrior, Province)		G/E	G/E	F			G		G/E				Flares aphids and mites
Gamma-Cypermethrin (Respect, Mustang)		G/E	G/E	F			G		G/E				Flares aphids and mites
Cyromazine (Trigard)													Not used
Deltamethrin (Battalion)		G/E	G/E	F			G		G/E				

Management tools	Aphid/PVY and PLRV	Beet leafhopper/ phytoplasma/ purple top	Colorado potato beetle	Caterpillars (cutworm, armyworm, looper)	Flea beetle	Lygus bug/stink bug	Psyllid/Liberibacter/zebra chip	Slug	Spider mite	Thrips	Tuberworm	Wireworm	Comments
Dimethoate (Various Brands)	F	F							F	F			
Dinotefuran (Scorpion, Venom)					G								Not used in East WA/OR/ ID
Esfenvalerate (Asana, Adjorn)		G/E	G/E	F									Flares aphids and mites
Ethoprop (Mocap)												G	
Fipronil (Regent)												E	
Flonicamid (Beleaf)	E					G	E			F			
Hexythiazox (Onager)							G		E				
Imidacloprid (Many Brands)	E	E	G				F						
Indoxacarb (Avaunt)			G/E	E			G						
Malathion (Many Brands)													Not used
Methomyl (Lannate)						G				G			
Novaluron (Rimon)			G/E	E		F	G						
Oxamyl (Vydate)	F		F			G-E	F			F/G			
Permethrin (many brands)													Not used
Phorate (Thimet, Phorate)													Not used
Phosmet (Imidian)													Not used
Propargite (Comite)									G				
Pymetrozine (Fulfill)	E						E						Expensive
Spinetoram (Radiant)			G/E	E			G						Expensive

Management tools	Aphid/PVY and PLRV	Beet leafhopper/ phytoplasma/ purple top	Colorado potato beetle	Caterpillars (cutworm, armyworm, looper)	Flea beetle	Lygus bug/stink bug	Psyllid/Liberibacter/zebra chip	Slug	Spider mite	Thrips	Tuberworm	Wireworm	Comments
Spinosad (Success, Entrust, Blackhawk)				G			G			G	G		
Spiromesifen (Oberon)							E		E				
Spirotetramat (Movento)	G/E						G						
Sulfoxaflor (Transform)	E					G	G						
Thiamethoxam (Actara, Cruiser, Platnum)	E	G	E				G						
Tolfenpyrad (Torac)	**G**		G	G			G			G			Hard on beneficials
Stylet Oil													Not used
Fumigants													
1,3-Dichloropropene (Telone II)												E	
Metam sodium (Sectagon, Vapam HL)													Indirectly controls insects such as Colorado potato beetle or wireworm
Unregistered/new chemistries													
Inscalis	G												Registered on potato
Cultural/nonchemical strategies													
Preservation of beneficial insects													
No pyrethroids before June 15													

Efficacy ratings for WEED management tools in potato

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

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

*In "Type" column, Pre = soil-active against pre-emerged weeds; Post = foliar-active against emerged weeds.

Management tools	Type*	Annual broadleaf (kochia, nightshades, pigweeds, etc.)	Perennial broadleaf (field bindweed, Canada thistle, etc.)	Annual grasses (barnyard grass, etc.)	Perennial grasses (quackgrass, etc.)	Comments
Clethodim (Select)	post			G		
Dimethenamid-P (Outlook)	pre	G				
EPTC (Eptam)	pre/post	P		G		
Ethalfluralin (Sonalan HFP)	pre/post	G		G		
Flumioxazin (Chateau)	pre	G		?		Time sensitive
Fomesafen (Reflex)						
Metolachlor (Stalwart or others)						No present uses
Metribuzin (TriCor DF 75%)	pre/post	F		F		Declining efficacy
Paraquat (Gramoxone SL, Inteon, Firestorm)	pre	E				Nonstorage only. Best in heat, pre or defoliant only
Pendimethalin (Prowl 3.3 or H2O)	pre	G		E		
Rimsulfuron (Matrix)	pre/post	G		G		Timing is important
S-metolachlor (Dual Magnum)	pre/post	F				
Sethoxydim (Poast Plus)				G		
Trifluralin (Treflan or others)	pre/post	G		G		
Vapam HL	pre	G		G		
Unregistered/new chemistries						
Cultural/nonchemical strategies						
Cultivating	pre/post					
Harrowing	pre/post					
Dammer diking	pre/post					

Using PAMS Terminology

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

P PREVENTION

Prevent introduction to the farm

- Pest-free seeds, transplants

Prevent reservoirs on the farm

- Sanitation procedures
- Eliminate alternative hosts
- Eliminate favorable sites in and off crop

Prevent pest spread between fields on the farm

- Cleaning equipment between fields

Prevent pests developing within fields on the farm

- Irrigation scheduling to prevent disease development
- Prevent weed reproduction
- Prevent pest-susceptible perennial crops by avoiding high-risk locations

A AVOIDANCE

Avoid host crops for the pest

- Crop rotation

Avoid pest-susceptible crops

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

Avoid crop being the most attractive host

- Trap cropping
- Use of pheromones
- Use crop nutrition to promote rapid crop development

Avoid making the crop excessively nutritious

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

Avoid practices that increase the potential for pest losses

- Narrow row spacing
- Optimized in-row plant populations
- No-till or strip till

M MONITORING

Collect pests

- Scouting and survey approaches
- Traps

Identify pests

- Use of identification guides, diagnostic tools and diagnostic laboratories

Identify periods or locations of high pest risk

- Use weather-based pest-development and risk models
- Use soil and plant nutrient testing

Determine status and trends in pest risks and classify pest severity

- Maintain pest records over time for each field

Minimize pest risks over time

- Plan an appropriate PAMS IPM strategy, based upon pest status and trends

Determine interventions based upon risks and economics

- Use of decision-support tools, economic thresholds

S SUPPRESSION

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

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

Pesticide risk classification

Paul Jepson, Oregon State University

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

1. Risk to aquatic life

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

2. Risk to terrestrial wildlife

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

3. Risk to pollinators

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

4. Inhalation risk

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

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