Pest Management Strategic Plan
for
Pacific Northwest Potato Production

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The use of trade names does not imply endorsement by the work group or any of the organizations represented. Trade names are used as an aid in identifying various products.

Background

In its native habitat, the potato is a perennial plant. It survives from year to year as an underground stem known as a tuber. However, potatoes are grown as an annual crop and are propagated vegetatively by planting tubers or seed pieces, rather than true seeds. The cropping cycle varies from 90 to 150 days depending upon the growing region. There are four stages of growth and development in the potato plant: vegetative growth, tuber initiation, tuber growth, and maturation. The growth pattern can be influenced by cultivar, age of seed pieces, weather, cultural practices, and pest damage, as well as a variety of other environmental factors.

The edible portion of the potato grows underground. In many areas, before harvesting the crop, the above-ground portions, or vines, are killed. Some early processed varieties like "Shepody" are harvested with the green vines still attached. Crops intended for storage are usually harvested 10 to 21 days after vine-kill.

In Idaho, most major production areas are adjacent to the Snake River Plain in Southern Idaho where water is available for irrigation. Sprinkler irrigation is used on more than 99% of the crop. Major production regions include the southwest (7% of potato acreage, 8% of production), south-central (28% of potato acreage, 32% of production), and east (65% of potato acreage, 59% of production).

In Oregon, the bulk of the crop is grown in the central and eastern parts of the state. Growers irrigate all potatoes in Oregon and 70% of the acreage is irrigated by center pivot systems.

In Washington, potatoes are primarily produced in the eastern part of the state in the Columbia Basin and along the Snake River where water is available for irrigation. Sprinkler irrigation is used on about 90% of the crop and furrow irrigation on the remainder. A small portion of the potato crop, mainly fresh market and seed potatoes, is produced in the Skagit Valley and Whatcom County, respectively, of Western Washington.

The commercial production of potatoes in Alaska occurs mainly in the Matanuska Valley due to its proximity to Anchorage. Major production regions include the south-central (Mat-Su Valley, 59% acreage; 84% production) and the interior (Delta, Fairbanks, 38% acreage; 15% production).

EPA and FQPA

EPA is now engaged in the process of re-registering pesticides under the requirements of the Food Quality Protection Act (FQPA). The Agency is examining dietary, ecological, residential, and occupational risks posed by certain pesticides. EPA's regulatory focus on the organophosphate (OP), carbamate, and B2 carcinogen pesticides has created uncertainty as to these pesticides' future availability to growers. At some point, the EPA may propose to modify or cancel some or all uses of these chemicals on potatoes. The regulatory studies that EPA requires registrants to complete may result in some companies voluntarily canceling certain registrations for potatoes.

The USDA, the EPA, the land-grant universities and the potato industry need to pro-actively identify research and regulatory needs for reducing the reliance on certain pesticides with effective alternatives if it should become necessary as a result of EPA's regulatory actions.

The Work Group

A work group consisting of growers, commodity groups, pest control advisors, regulators, university and USDA specialists, and other technical experts in Alaska, Idaho, Oregon, and Washington met for two days in Boise, Idaho. The purpose of the meeting was to identify the needs of potato growers in Alaska, Idaho, Oregon, and Washington with reference to possible regulatory actions regarding pesticides and the FQPA. This exercise resulted in a list of critical needs, general conclusions, tables listing the efficacy of various management tools for specific pests, and a comprehensive transition foundation containing many pest-specific critical needs.

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

Research

1. Develop alternatives to chemical control: resistant varieties, cover crops, crop rotations, IPM research that includes green manure / cover crops, biological control (efficacy, agronomics, economics).
2. Investigate pesticide resistance management including development of new substitution chemistries to combat resistance.
3. Develop reliable sampling methods for detection of pests and establish accurate action threshold levels.
4. Develop comprehensive pest-predictive modeling systems.
5. Influence the development of new chemistries as needed.
6. Continue research and education on genetically modified organisms (GMOs).
7. Continue plant breeding programs for disease and pest resistance.
8. Study the biology of weeds, diseases, insects, and nematodes and their interactions in the potato cropping system.
9. Investigate pesticide impact on beneficial and other non-target organisms.
10. Address seed quality and seed-transmissible disease issues.

Regulatory

1. Accelerate and increase priority for the registration process for potato pesticides.
2. Preserve organophosphate and carbamate chemistries until suitable alternatives for the same pest spectrum are developed.
3. Allow resistance management as a justified need for the Section 18 Registrations.
4. Preserve current application methods based on sound science and real-world data and use.
5. Regulate and enforce strict seed certification and quarantine standards across state and national borders.
6. Regulate non-potato industry sources of pests (greenhouses, home orchards, gardens, etc).

Education

1. Increase proactive public education to raise consumer confidence about safe pesticide use by potato growers in the United States and point out potential risks of imported potatoes / potato products grown under different regulatory standards.
2. Educate consumers about benefits of genetically modified organisms (GMOs).
3. Create an on-line clearinghouse for research data.
4. Increase interdisciplinary pesticide resistance management education for growers, crop advisors, and regulators.
5. Educate growers about importance and methods of scouting and economic thresholds.
6. Develop forecast prediction modeling and pest identification for web-based access by growers, consultants, and extension and research personnel.
7. Educate consumers about potential potato pests.
8. Increase consumer education about the realities of modern farming and living with the constraints of pest management regulations.

Genetically Modified Potatoes

Potato varieties that have been genetically enhanced have the potential to provide effective management alternatives for a number of pest-related problems involving insects, diseases, and weeds. Colorado potato beetles have been managed using genetically modified potatoes; this was an effective strategy before such varieties came into disfavor. Genetically modified potatoes have also been generated that prevent or reduce damage due to potato leafroll virus and potato virus Y. The mosaic viruses of potato, including strains of potato virus Y and potato virus A, as well as others, have proven all but impossible to adequately manage using current control strategies. Genetically enhanced potato varieties show enormous potential in this vital area of disease management. Other important disease management issues such as potato late blight and early blight may also be addressed using genetically enhanced potato varieties.

Genetically modified potatoes tolerant to glyphosate (Roundup) have been generated. Weed control using glyphosate alone, or standard soil-residual herbicides in combination with glyphosate, has been demonstrated in research trials to provide excellent weed control, and good return on the weed control dollar invested.

Currently, however, there are barriers to the adoption of genetic enhancement technology. There is a need for research and education regarding the safety and environmental impact of GM potatoes. There is a need to show low risk in terms of an environmental impact or effects on non-target organisms. The use of GM potato technology has the potential to reduce the use of pesticides, particularly insecticides but also herbicides and fungicides. Additionally, genetically enhanced crop varieties should be very useful in developing countries. A number of emerging technologies are or will become available for the genetic modification of potatoes.

Foundation For Pest Management Strategic Plan

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

PRE-PLANT

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

The rotation of potatoes with other crops is an integral part of the pre-plant pest-control strategy. The benefits of crop rotation include better control of nematodes, diseases, and weeds. Other benefits derived from rotational crops include loosening of compacted soil by growing cereal with fibrous root systems, deriving additional nitrogen from a legume crop (e.g., alfalfa or beans), incorporation of organic matter from crops such as small grains and corn, and nutrient carryover from vegetable or other high-input crops. Primary tillage is a cultural practice that incorporates residue from the previous crop, reduces wheel traffic compaction from the previous season, improves water filtration and soil aeration, controls weeds and nematodes, loosens the soil for root penetration, and provides a suitable seedbed.

Prior to current crop, herbicides are used to control weeds that escape control procedures used with rotational crops. Soil-applied herbicides for these rotational crops, when also labeled for potatoes, are avoided to prevent adaptation of microbial populations capable of reducing the efficacy of such herbicides in potatoes. Where possible, growers avoid crops that will not provide good control of weeds that are difficult to control in potatoes. Growers may be restricted in their use of herbicides in rotational crops if herbicide carryover in the soil from applications made in previous crops can damage the potato crop to be planted.

Soil sampling and analysis determines soil fertility, chemistry, and physical characteristics, as well as nematode and wireworm population levels. Fertilizer applications are made at the pre-plant stage.

In the fall or spring prior to planting a potato crop, fumigation is commonly used to control nematodes, diseases (Verticillium wilt) and weeds. Fumigants are properly incorporated and contained in the soil by tillage and proper soil moisture. Timing of fumigation is scheduled to take advantage of the most effective soil temperatures, to target the most susceptible stage of pests, and to avoid the presence of damaging fumigant residues at planting.

Nematodes

Nematodes are one of the major limiting factors for potato production in the Pacific Northwest. Nematode infestation results in yield decline and reduction in quality, thereby contributing to economic loss to the industry. Predominant nematode pests identified in rhizospheres of potatoes are root-knot nematodes (*Meloidogyne* spp.), root-lesion nematodes (*Pratylenchus* spp.), and stubby-root nematodes (*Trichodorus* and *Paratrichodorus* spp.). There is an interaction between *Pratylenchus* spp. and Verticillium wilt. Nematodes are also a concern to potato growers because they are vectors of tobacco rattle virus.

Cultural practices for nematode control include reduction of crop residue through tillage and avoiding rotation crops and weeds that may promote increased nematode population levels. Soil sampling and analysis, as well as knowledge of field history, is used to determine nematode population levels. When nematode population densities exceed the economic threshold, most growers will apply chemical nematicides. Soil fumigation with metam sodium (Vapam, Metam, Busan) or 1,3-dichloropropene (Telone-II) is the most cost-effective chemical method for controlling root-knot nematode. . Irrigation is needed to bring the soil moisture up to 70 to 80% at least one week prior to making the application. Soil moisture is the single most critical factor at the time of application for metam sodium products. Metam sodium (Vapam, Metam, Busan) requires moisture to move through the soil and come into contact with pathogens and pests. 1,3-dichloropropene (Telone II) is effective on stubby-root nematodes at the high rate. Since metam sodium (Vapam, Metam, Busan) is a contact nematicide it is not effective against the nematodes inside the root debris or stubby-root nematodes. Non-fumigant systemic nematicides are the most cost-effective chemical method for controlling root lesion and stubby-root nematodes.

Green manure crops (crops that are incorporated into the soil while still green) can be used early during the pre-plant stage. Oil radish or rapeseed crops are planted in the fall before planting the potato crop the following spring. These green manure crops are incorporated into the soil before “freeze-up.” Consistent application of manures (organic matter) results in some nematode control. High ammonia concentrations improve efficacy. Manure also encourages beneficial organisms that can suppress nematode population.

Root-knot nematodes (*Meloidogyne* spp.) are of particular concern to the potato industry. Columbia root-knot nematode (*Meloidogyne chitwoodi)* and Northern root-knot nematode (*M. hapla)* are endoparasites found in abundance in many areas, especially in sandy soils. They have been recognized as pests in potatoes for a long time. Infestation can render tubers unmarketable. When the level of infected tubers exceeds 5%, processors and packers generally reject all potatoes from that field. These nematodes have a wide host range leading to population increases when potatoes or other susceptible crops are grown following potatoes. Aldicarb (Temik) applied at planting in combination with ethoprop (Mocap), pre-plant fumigation with 1, 3 dichloropropene (Telone II), or metam sodium (Vapam, Metam, Busan) is an effective management tool. Aldicarb (Temik) exhibits systemic and contact nematicidal activity. In addition, aldicarb (Temik) is highly water-soluble and is able to deeply penetrate the soil, making it effective against mobile nematodes. Effective weed control is employed before and during potato culture because the nematodes have many weed hosts and are able to move to the crop quickly. For Columbia root-knot and northern root-knot nematodes, growers treat with ethoprop (Mocap) and aldicarb (Temik) for populations between 10 and 50 nematodes per 500 cc soil. Growers fumigate if population counts exceed 50 nematodes per 500 cc soil. Aldicarb (Temik) and ethoprop (Mocap) are not needed on potatoes that follow fall-plowed alfalfa because the roots freeze and deteriorate during the winter, decreasing the nematode population due to winterkill. After sampling, but before planting, growers who fumigated sometimes use aldicarb (Temik) to reduce nematode populations if they remain high.

Root-lesion nematodes that feed inside the root system (endoparasites) can be controlled with aldicarb (Temik), a systemic pesticide. Aldicarb (Temik), applied at planting, remains in the root system and soil profile for 6 to 8 weeks. When eggs hatch, this long residual results in nematode control. Research at the University of Idaho shows that controlling root-lesion nematode populations has a positive impact on tuber yield. Twenty pounds of aldicarb (Temik) applied at planting significantly reduced root-lesion nematode populations and increased tuber yield an average of 38.3 cwt/A. Years of research and grower experience along the Snake River Plain of Southern Idaho have also proven that aldicarb (Temik) applications often result in verticillium wilt (early die) suppression with accompanying yield response. These results may be due to several positive effects caused by aldicarb (Temik) including root-lesion nematode control, impact on the development of *Verticillium microsclerotia* or plant growth regulatory effects. Treatment thresholds for aldicarb (Temik) have been developed. The threshold for *P. neglectus* is when counts are 2000 nematodes per 500 cc soil in fields with no history of early die. If early die is present, the threshold for treatment is when *P. neglectus* counts reach 100. In fields infected with *P. penetrans*, the treatment threshold is 100, regardless of the early die situation.

Stubby-root nematodes (*Paratrichodorus* spp.) are difficult to control because of their mobility in the soil. This nematode is highly sensitive to change in soil moisture and temperature. Fluctuation in these two factors causes the nematode to move up and down in the soil profile. Stubby-root nematodes can reside at soil depths of more than 40 inches. When these nematodes migrate deep in the soil profile, they are difficult to control with a fumigant such as 1, 3-dichloropropene (Telone II). Because ethoprop

(Mocap) and metam sodium (Vapam, Metam, Busan) are contact nematicides, their application does not effectively control stubby-root nematodes. 1,3-dichloropropene (Telone II) must be applied at high usage rates, which result in increased input costs. Aldicarb (Temik) application at 20 lbs/A is very effective in controlling stubby-root nematode. Aldicarb's (Temik) systemic activity also affects nematodes as they feed on the root system of treated potato plants. Efficacy of the nematicides on stubby-root nematode differs with respect to application method in the field.

Corky ring spot disease is a symptom of tobacco rattle virus, which is vectored by stubby-root nematode. Corky ring spot incidence ranges from 6 to 55% and leads to significant differences in total and marketable yields. Aldicarb (Temik) applied in-furrow at planting, modified in-furrow at planting, or in-furrow at planting in combination with foliar applications of oxamyl (Vydate) result in the lowest incidence of corky ring spot disease and the highest total and marketable yields.

Oxamyl (Vydate) is a systemic nematicide hence it is very effective in controlling all nematodes. However, oxamyl (Vydate) is sensitive to pH, creating a major constraint in its use. Also, oxamyl (Vydate) has a short half-life, requiring multiple applications during the growing season. Oxamyl (Vydate) is more effective when used in combination with other nematicides such as aldicarb (Temik) or ethoprop (Mocap) at planting.

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

Research

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

- Develop uniform nematode control standards for the entire PNW.

Regulatory

- Hasten registration of new pesticides, including fosthiazate.

Education

- Develop a comprehensive PNW nematode website.
- Increase grower education concerning the importance and cost-effectiveness of pre-fumigation irrigation.
- Distribute available information pertaining to the use of dairy manures for nematode control.

Diseases

Two classes of disease organisms are important during the pre-plant phase. First are the organisms that are endemic to soils in which potatoes are produced. These are mainly fungal and bacterial pathogens that infect potato plants during growth and harvest. Second are the seed-borne diseases that are not present in the crop unless they are imported with the seed. These organisms include fungal, bacterial, and viral pathogens.

Key soil-borne diseases include Verticillium wilt, early blight, pink rot, Pythium, common scab, powdery scab, blackdot, Rhizoctonia, white mold, Fusarium dry rot, soft rot, and tobacco rattle virus (which causes corky ringspot; this virus is nematode-vectored and thus acts like a soil-borne disease). Key seed-borne diseases include the major viruses potato leaf roll virus (PLRV), potato virus Y (PVY), potato virus X (PVX), potato virus A (PVA), bacterial ringrot, late blight, and silver scurf. Many diseases that survive in the soil are made worse by seed-borne inoculums such as powdery scab, blackdot, Rhizoctonia, Fusarium dry rot, and soft rot.

Crop rotation is important in controlling most soil-borne diseases. Rotating with non-host species can dramatically reduce the inoculum level of most soil-borne disease organisms. Grass and legume crops are especially effective at reducing soil inoculum. The most effective control of seed-borne diseases is the purchase and use of certified seed (see the planting section for other control methods). Other important off-season disease-control practices include control of volunteer potatoes and elimination of potato cull piles.

As discussed for nematodes, growers who use a cover crop such as Sudangrass or mustards (*Brassica* spp.) provide some control of soil-borne diseases through biofumigation. This is only feasible in areas with a long growing season.

Partial control of soil-borne diseases is achieved through proper tillage. Fall soil preparation and prebedding reduce compaction and its associated root health problems, and encourage breakdown of plant residues that may harbor some disease organisms.

With sandy soils, growers leave some plant residues on the soil surface to prevent soil erosion. In this case, fall tillage is minimal.

Other important non-chemical methods for controlling diseases include choosing resistant varieties, optimizing management practices (especially nutrition and irrigation), and prevention of plant stress. Many of these factors are directly impacted by pre-plant tillage, fertilization, and general management practices.

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

In the case of corky ringspot and possibly *Verticillium*, soil sampling can be used to detect diseases in the field. With corky ringspot, growers sample for the stubby-root nematode.

Fumigation is one effective chemical control method for many soil-borne diseases. The most common fumigants are metam sodium (Vapam, Metam, Busan), 1,3-dichloropropene (Telone II), and metam potassium (K-Pam). Applications are made by chemigation and chisel plow. Growers ensure proper soil moisture at the time of application for maximum efficacy. If insufficient or excess moisture is present , fumigants will not work well. 1, 3 dichloropropene (Telone II) is an extremely important chemical at this crop stage. Pink rot is partially controlled through foliar and soil applications of mefanoxam (Ridomil).

Growers achieve significant reduction of early die, caused by *Verticillium* spp., by using soil fumigants like metam sodium (Vapam, Metam, Busan) before planting. This is typically done in the fall, but can prove effective in spring.

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

Research

- Conduct definitive studies on the effects of fumigation on the total bio-population in soil, including the impact on non-target organisms such as beneficial nematodes. Document interactions and measure the balance between risks and benefits.
- Continue to research the efficacy of cover crops, green manures, and animal manures (interdisciplinary research). Include work to identify new varieties of green manures for short-season areas, including green manures

that can over winter. Identify sources of long-term funding for green-manure research.

- Continue research on the relative importance of seed-borne vs. soil-borne inoculum for soil-borne diseases such as verticillium, Rhizoctonia, soft rot, and dry rot, and silver scurf.
- Investigate recommended rates of Telone II fumigant with the intent to document efficacy at lower rates.
- Identify new fumigants/chemicals for control of some soil-borne diseases such as pink rot.
- Devise soil-sampling strategies to assess pathogen populations in the soil and establish useable thresholds for treatment.
- Discover new technologies for soil sampling—more credible measures.
- Investigate presence, damage, and control of powdery scab.
- Continue plant breeding programs for host plant resistance.

Regulatory

- Implement strong quarantine measures to keep out pathogens not yet established here.
- Implement aggressive surveillance to support quarantine.
- Have public institutions carry more of the burden of obtaining new pesticide registrations to supplement and accelerate the process.
- Improve the process for obtaining Section 18 registrations.
- Strengthen rules for seed certification.

Education

- Educate regulators about pest resistance problems and issues.
- Educate farm workers on use of fumigants to improve application safety.
- Educate neighbors on the application process to reduce concerns from the non-farming population.
- Construct an Internet website with pest and pesticide information to increase the availability of appropriate information.
- Educate growers on the economic and biological value of using green manures.

Insects

Wireworms are the major insect concern at the pre-plant crop stage. Growers consider wireworms to be moderate to serious pests. Larvae feed upon potato seed pieces and underground stems during the spring. The early feeding opens the seed pieces and stems to rotting organisms (fungi and bacteria) that result in poor or weak stands. More serious damage occurs on developing tubers later in the season. This damage, although it occurs at a different growth stage, is still considered a pre-plant problem because pre-plant is the only period during which control measures can be applied. In the processing industry, there is a zero tolerance for the presence of wireworm in the raw product because the hard body of this insect is classified as foreign material. This situation, combined with the fact that there are few effective control measures, makes wireworm a difficult pest to manage. Further, certain crops grown in rotation with potatoes (e.g., cereals) also are wireworm host plants and so increase infestation levels.

Fields can be sampled during the pre-plant stage for wireworm infestations but the process is so labor-intensive that few growers practice it. Ethoprop (Mocap) and occasionally diazinon are applied pre-plant for control. A few insecticides are labeled for control of wireworm, but no chemical alone can clean up a heavily infested field; rather, combinations of insecticides and fumigants may be required.

Some insecticides labeled for wireworm control:

- ❖ Ethoprop (Mocap) – one of the most effective compounds. Shown to occasionally lack efficacy at some locations in Idaho. Also has nematicidal activity.
- ❖ Phorate (Thimet) – often effective.
- ❖ Diazinon – inexpensive, but effective only in cases of light infestation. There is a Section 24C registration in ID, OR, and WA.
- ❖ Carbofuran (Furadan) – labeled for suppression only.

1,3-dichloropropene (Telone II), used as a fumigant, can be effective at reducing populations of wireworm if it is applied after the soil warms during the spring.

Green peach aphids can be managed at this stage by controlling volunteer potatoes in prior crops with herbicides.

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

Research

- ❖ Improve sampling techniques to increase cost effectiveness and reliability of wireworm detection. The method must provide sufficient data in the spring, when control measures can be applied, to be of use in making control decisions.
- ❖ Research on wireworm adults that will allow control at that stage (attract and kill).
- ❖ Investigate the effect of crop rotations and cover crops on wireworm populations.
- ❖ Investigate the biology of wireworms in potatoes.
- ❖ Pesticide testing:
    - o More development, research, and new product testing. Products for wireworm control in potatoes are considered minor use, therefore there is little interest by agrochemical companies for product development. Much of this will need to be public work.
    - o Evaluate new chemistries: Fipronil, Aztec, others.
    - o IR-4 involvement with new registrations.

Regulatory

- Work with EPA in addressing FQPA issues to provide realistic and commonsense risk assessment data in order to avoid loss or cancellation of commonly used/needed pesticides.
- Work with FDA to analyze the zero tolerance requirement of wireworm presence in potatoes for processing.

Education

- Educate regulators concerning the seriousness of wireworm control issues.
- Educate fieldmen and producers concerning all elements of control – detection, chemical efficacy, proper timing, etc.
- Educate agrochemical dealers and consultants concerning the selection of appropriate pesticides.

Weeds

Weeds can cause a 15% or greater yield loss in potatoes if not controlled. Pigweed and barnyardgrass, for example, at a density of one plant per yard of row, can reduce potato yield by 19 to 33%. Most growers plan their weed control and herbicide programs for the current potato crop before planting based on field history, scouting, and potato variety selection. For control of most broadleaf weeds, and some grassy weeds, metribuzin (Sencor), EPTC (Eptam), s-metolachlor (Dual), pendimethalin (Prowl), trifluralin (Treflan), and rimsulfuron (Matrix) may be used in potatoes. Metribuzin (Sencor) can cause injury on white and red skinned, early maturing, smooth skinned varieties. Most growers wait to apply herbicides preemergence or postemergence at lay by or last final hilling. Although most herbicide applications are post plant, s-metolachlor (Dual), EPTC (Eptam), or trifluralin (Treflan) may be applied and incorporated prior to planting. Some important weed control measures occur pre-plant. One important measure is the use of best weed control practices in all rotation and cover crops. This effectively reduces the seed bank for most weeds. Cultural controls are also important. Fall irrigation accompanied by tillage eliminates most volunteer crop plants and kill some endemic weeds. Some pre-plant spring tillage, even if minimal, also provides control of early-emerging weeds.

To control volunteer grain, paraquat (Gramoxone Extra) or glyphosate (Roundup) is occasionally applied pre-plant. This is especially important in fall-bedded fields that are not tilled prior to planting. Fumigation, although not used for weed control, may provide 50% early weed control. Bio-fumigation is sometimes used to control some early weeds.

Volunteer potatoes can be a serious weed control issue in rotational crops. Volunteer potatoes can compete with the crop, as well as serve as sources of aphids and inoculum for PLRV and late blight. Volunteer potatoes are very hardy, making their control difficult. An integrated approach is required for good control. The growth regulator maleic hydrazide applied to the potato crop (potatoes not grown for seed) can reduce volunteers in subsequent rotational crops. Several herbicides are registered in various rotational crops that can contribute to volunteer potato control. Most recently registered compounds are carfentrazone (Aim) in small grains and corn, mesotrione (Callisto) in corn, and fluroxypyr (Starane) in small grains. A Section 18 emergency exemption has been granted for fluroxypyr (Starane) in corn in recent years, and for 2002 as well.

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

Research

- Discover new chemicals that are safer on the crop grown in sandy and low-organic-matter soils.
- Evaluate additional products for controlling hairy nightshade, black nightshade, and cutleaf nightshade.
- Develop herbicides with shorter residuals to help with rotation problems.
- Develop herbicides with new modes of action, especially for control of triazine-resistant weeds (pigweed and common lambsquarter).
- Continue herbicide-resistant GMO research.
- Explore the use of weed-suppressing cover crops and green manures using an interdisciplinary research approach.
- Examine linkages of cultural practices for other pests and the impact these cultural practices have on weed control.
- Evaluate winter annual weed control and the relationship of these weeds as hosts for other insect and disease pests.

Regulatory

- Expand labels to allow for fall applications of herbicides to match changes in cultural practices.
- Review surface and ground water issues related to environmental issues (e.g., buffer zones) with the result being an understandable, applicable global policy.

Education

- Educate growers and crop advisors on the use of green manure systems for weed management.
- Educate all applicators on herbicide mode of action for resistant-weed management.
- Provide web-based efficacy information.

PLANTING
(FEBRUARY 15 – JUNE 10)

- **COLUMBIA BASIN WA, OR—FEBRUARY**
- **TREASURE VALLEY OR, ID—MARCH - APRIL**
- **MAGIC VALLEY ID—MARCH - MAY**
- **WEST OF THE CASCADES (OR AND WA)—APRIL**
- **SOUTHEASTERN IDAHO—APRIL - MAY**
- **EASTERN IDAHO—APRIL - JUNE**
- **ALASKA—MAY**

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

Cultural practices used at planting include reducing time between cutting seed pieces and planting to minimize seed piece decay; monitoring seed piece size since small pieces lead to weaker plants, which are more susceptible to disease; monitoring soil temperature for proper planting time; and maintaining proper planting depth. Hilling allows the use of a shallow seed piece planting for rapid emergence, while providing the soil depth necessary later in the season for proper tuber development and reduced exposure to sunlight and adverse temperatures. Exposed tubers develop a green color from chlorophyll formation. Glycoalkaloid levels typically are higher in the skin and cortex of green tubers and, along with chlorophyll, cause a bitter taste. Timing of the hilling operation can affect season-long weed management decisions. For example, if hilling is done at planting, a grower will not be controlling weeds with another hilling operation at or near emergence. Growers must rely on other means of weed control from planting to row closure and beyond, potentially requiring multiple herbicide applications.

Management of potato cull piles is a critical sanitation issue. Variety selection influences which pest growers have to manage during the growing season. Frequently, growers do not have a choice as to which varieties they plant because the variety is dictated by the contracting processor or packer.

Several fungicides and insecticides are used at planting (**Table 1**). These can be divided into products used as seed treatments during the seed cutting operation and those used as in-furrow treatments during planting. Some products are pre-mixes of more than one fungicide, or of fungicide(s) and an insecticide. There is also at least one seed treatment bactericide, streptomycin sulfate (Agri-Mycin, Streptrol).

Table 1. Seed treatment and in-furrow fungicides and insecticides as of April, 2002.

Product Name	*Active Ingredients*	
	Fungicides	Insecticides
Seed-Piece Treatments		
Captan	captan	
Evolve	Thiophanate-methyl, mancozeb, cymoxanil	
Genesis		imidacloprid
Maxim	fludioxonil	
Maxim MZ	fludioxonil, mancozeb	
Moncoat MZ	flutolanil, mancozeb	
Tops MZ	Thiophanate-methyl, mancozeb	
Tops MZ Gaucho	Thiophanate-methyl, mancozeb	imidacloprid
Soil Applications		
Admire		imidacloprid
Blocker, PCNB	PCNB	
Diazinon		Diazinon
Di-syston		disulfoton
Furadan		carbofuran
Mocap		ethoprop
Moncut	flutolanil	
Phostrol	Phosphates, mono- and dibasic sodium, potassium, and ammonium	
Platinum		thiamethoxam
Platinum Ridomil Gold	mefenoxam	thiamethoxam
Quadris	azoxystrobin	
Ridomil Gold, Ultraflourish, Flouronil	mefenoxam	
Ridomil Gold MZ	mefenoxam, mancozeb	
Ridomil Gold Bravo	mefenoxam, chlorothalonil	
Ridomil Gold Copper	mefenoxam, copper	
Temik		aldicarb
Thimet, Phorate		phorate
Vydate		oxamyl

Nematodes

Sampling is the basis for determining the occurrence and distribution of potato nematodes. Making the proper management decision for a nematode problem depends on the correct diagnosis, which also depends on proper sample collection, processing, and analysis. Climate, crop rotation, weed hosts, chemicals used, and other factors that may lead to patchy distributions often affect population densities.

In fields not fumigated in the fall, non-fumigant nematicides can be used at planting or post planting. Non-fumigant nematicides such as ethoprop (Mocap), aldicarb (Temik), and oxamyl (Vydate) effectively control root-lesion nematodes. Aldicarb (Temik), and oxamyl (Vydate) effectively control stubby-root nematodes. Aldicarb (Temik) cannot be used on early-harvested varieties or in short-season areas due to the 150-day pre-harvest interval. Ethoprop (Mocap) is not effective on stubby-root nematodes. Aldicarb (Temik) can only be applied on sprinkler-irrigated fields. Spring soil sampling (pre-plant) for nematodes is critical.

Ethoprop (Mocap) in combination with other nematicides is an effective approach for root-knot and root-lesion nematode management. However it is not effective for stubby-root nematode management.

Preliminary testing of fosthiazate has been conducted at the University of Idaho on root-knot nematodes and results show good efficacy. Additional testing is needed to examine efficacy of fosthiazate on stubby-root nematode.

Critical Needs for Management of Nematodes in PNW Potatoes at Planting

Research

- Increase research on oxamyl (Vydate) application rate, method of application, and timing.
- Investigate fosthiazate application rate, method of application, and timing.
- Determine efficacy of lower rates of nematicides.

Regulatory

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

Education

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

Diseases

Growers use certified seed to produce a quality potato crop and to assure initially low levels of viruses such as PLRV and PVY. Growers reduce the incidence of early die, caused by *Verticillium* spp., by using soil fumigants like metam sodium (Vapam, Metam, Busan) before planting. This is typically done in the fall, but can prove effective in spring.

Growers with fields that have significant root-knot nematode populations or a history of corky ring spot virus problems fumigate with a material effective against nematode pests and vectors. Applications are typically made in the fall.

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

Growers attempt to plant seed, weather permitting, when soil temperatures are between 45 and 65 degrees F. Low soil temperatures delay wound healing in the seed, which can lead to seed-piece decay, while high temperatures, especially if soils are excessively moist, can also lead to seed piece decay problems. For fields or areas where soft rot seed-piece decay is known to be a problem, either single drop seed (small, whole seed tubers) or cut seed that has been healed or "suberized" is used. *Rhizoctonia* is managed with either a seed-piece treatment or application of an in-furrow chemical treatment.

Pink rot and pythium leak of potato are usually considered to be either late-season or storage disease problems, but an in-furrow application of mefenoxam (Ridomil Gold, Ultra Flourish) for management of these two diseases has been shown to be effective. The same fungicides can be applied to the foliage during the growing season when the tubers are about a half-inch in diameter to aid in management of these two disease problems.

Critical Needs for Management of Diseases in PNW Potatoes at Planting

Research

- Develop improved methods for managing soft rot.
- Develop an accurate assay for Rhizoctonia in the soil and on the seed piece to predict potential disease problem.
- Develop detection methods for late blight in seed, especially at very low levels.
- Investigate biology of silver scurf organism in regard to resistance development.

- Investigate the need for using both a seed-piece treatment and an in-furrow treatment for *Rhizoctonia*.
- Investigate azoxystrobin (Quadris) resistance management issues for early blight.
- Develop alternatives to in-furrow mefenoxam (Ridomil Gold, Ultra Flourish) treatment.
- Investigate high versus low volume rate of in-furrow treatment of mefenoxam (Ridomil Gold, Ultra Flourish).
- Develop a control measure (e.g., chemical, genetic, cultural) for black dot in seed.

Regulatory

- Enforce certified seed laws.
- Implement strong quarantine measures to keep out pathogens not yet established here.
- Implement aggressive surveillance to support quarantine.
- Standardize grower-driven seed certification across state lines. This is an issue growers need to address.

Education

- Increase awareness of importance of seed in spreading late blight and the difficulty of detection in seed.

Insects

The major insects of concern at planting are the green peach aphid (GPA), Colorado potato beetle (CPB), wireworms, and cutworms. The first two pests only attack the above-ground portions of the potato plants, whereas the latter two reduce stands by feeding on seed pieces and seedling plants. Phorate (Thimet) and carbofuran (Furadan) are applied at planting for early-season control of CPB and GPA, and to suppress wireworms. They have a short residual and do not give season-long control in longer-growing potato production regions. In Eastern Idaho, with a shorter growing season, phorate (Thimet) provides good control and additional pesticide applications may not be necessary. Imidacloprid (Admire), aldicarb (Temik), and thiamethoxam (Platinum) are applied to control CPB and GPA. Ethoprop (Mocap) is sometimes applied at planting for wireworm control. Vydate can also be applied at-planting for control of CPB, GPA, leafhopper, and flea beetle. A change to the pre-harvest interval on the aldicarb (Temik) label now prohibits post-emergence use. Therefore, when aldicarb (Temik) is used at this earlier crop stage to control these insect pests, additional chemical treatments are necessary at the end of the season to continue the control.

Critical Needs for Management of Insects in PNW Potatoes at Planting

Research

- Investigate efficacy of imidacloprid (Admire, Genesis, Gaucho) on wireworms.
- Develop anti-feedant or repellent-type compounds.
- To improve scouting efficiency, expand existing scouting programs, such as the Treasure Valley Pest Alert, to develop a regional early warning system.

Regulatory

- Work with EPA in addressing FQPA issues to provide realistic and commonsense risk assessment data in order to avoid loss or cancellation of commonly used/needed pesticides.
- Increase inspections on bedding plants in greenhouses and peach orchards to eliminate aphid reservoirs.

Education

- Educate public (homeowners) on efficacious treatments for overwintering populations of green peach aphid on backyard peach trees.

PRE-EMERGENCE
(21 TO 35 DAYS AFTER PLANTING)

Irrigation management to maintain soil moisture, cultivation, and application of herbicides are activities that growers engage in at the pre-emergence stage. Seed-piece condition is monitored for the presence of rot and for emergence. "Dragging off" (knocking the hills down until almost flat) is sometimes used to hasten emergence and aid in weed control.

Diseases

Irrigation management is used to avoid physiological stress at pre-emergence which helps manage soil-borne diseases such as *Rhizoctonia* and soft rot/blackleg. "Dragging off" is used to increase soil temperature at the seed depth, which also aids in management of soil-borne diseases. Cull piles are destroyed to reduce disease inoculum. Pythium leak is an occasional problem.

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

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

Research

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

Regulatory

- None.

Education

- Educate growers on what is known about powdery scab.

Insects

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

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

Research

- None.

Regulatory

- None.

Education

- None.

Weeds

Most potato herbicide applications are made pre-emergent to the potato crop. Weeds that can emerge early are controlled before the potato crop emerges with EPTC (Eptam), trifuluralin (Treflan), pendimethalin (Prowl), s-metolachlor (Dual), metribuzin (Sencor), and rimsulfuron (Matrix). EPTC (Eptam) or trifluralin (Treflan) must be incorporated. Most of these herbicides are applied by chemigation in Washington. Herbicides can be applied with a ground sprayer and sprinkler incorporated. A timely hilling operation just prior to a herbicide application before potato emergence is common in Idaho. Variety selection and crop rotation may dictate herbicide choice. EPTC (Eptam), trifluralin (Treflan), pendimethalin (Prowl), or s-metolachlor (Dual) will not control emerged weeds. Many herbicides are applied in a two- or three-way tank mixture, or sequentially with other herbicides in a planned program. Paraquat (Gramoxone Extra) and glyphosate (Roundup) are used for weed control prior to potato emergence when weeds are emerged and actively growing. Herbicides that are being tested for registration purposes include flumioxazin (Valor), sulfentrazone (Spartan), dimethenamid-p (Outlook), ethalfluralin (Sonalan), and flufenacet (Axiom).

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

Research

- ❖ Develop new herbicides, especially for white-skinned potatoes since metribuzin (Sencor) cannot be used.
- ❖ Develop chemicals with a new mode of action to aid in resistance management.
- ❖ Create a region-wide detection and monitoring system for new weed species and resistant weed.
- ❖ Evaluate variety response to new herbicides and plant-back effect on rotation crops.
- ❖ Investigate biological controls, e.g. weed-seed-eating beetles.
- ❖ Investigate herbicides used in rotational crops in the PNW to provide plant-back allowances for potatoes.

Regulatory

- ❖ Work with EPA in addressing FQPA issues to provide realistic and commonsense risk assessment data in order to avoid loss or cancellation of commonly used/needed pesticides.
- ❖ Allow the use of resistance management and crop rotation restrictions to justify Section 18 registrations.
- ❖ Pursue a Section 24c registration for the use of linuron (Lorox) in Alaska.

Education

- ❖ Educate growers about the location of resistant weeds and the active ingredients to which the weeds are resistant.
- ❖ Conduct a survey of resistant weeds in the PNW.
- ❖ Increase technology transfer to growers and crop advisors about new herbicides and how they should be used.

EMERGENCE TO HARVEST

Hilling operations in sprinkler-irrigated fields are performed when plants are emerging and hilling is completed before plants are too large so to minimize severe root pruning.

Discs, rolling cultivators, hilling listers, or implements with winged cultivator teeth are used.

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

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

For sprout suppression in storage, some growers apply maleic hydrazide (Royal MH-30) during the growing season. Timing during active growth is critical in order for the compound to be transported to the tubers and effectively suppress sprouting. Typical timing is about 11-12 weeks after emergence. Improper timing can result in non-effective sprout suppression, phytotoxicity, reduction in tubers per plant or size reduction, or cracking of the tuber skin. Cultivars differ in response to maleic hydrazide. Growers sometimes find application of chlorpropham (CIPC) necessary for tubers in storage, particularly long-term storage. Maleic hydrazide is also used for volunteer potato control. However, recent research at Washington State University has shown that the smaller tubers, which make up the majority of volunteer potatoes, also have the lowest residues of maleic hydrazide. These low residues are probably not enough to prevent the tubers left in the field from producing volunteer plants the following year.

Nematodes

After potatoes emerge, growers sample roots to determine presence and numbers of root-knot and lesion nematodes. If root-knot or lesion nematodes are detected in the soil or root samples, growers often use oxamyl (Vydate) at this crop stage because the effectiveness of aldicarb (Temik), which is applied at planting, has dissipated.

Potato-rot nematode (*Ditylenchus destructor*) is not widely present in Idaho but can cause devastating rot in stored tubers. High relative humidity is an essential factor for the establishment of this nematode. The effect of nematodes will manifest itself at harvest or storage, when infected tubers will rot.

Association of the potato-rot nematode with fungi has been reported to increase severity of host injury or to attract other pests such as mites and other nematodes. Dissemination occurs by introduction of infected tubers and in soil adhering to seed pieces.

Critical Needs for Management of Nematodes in PNW Potatoes at Post-Emergence

Research

- Develop slow-release nematicides.
- Study the impact of different combinations of nematicides.

Regulatory

- None.

Education

- None.

Diseases

At the post-emergence stage to harvest, late blight caused by *Phytophthora infestans* is the most damaging disease. The disease pathogen attacks stems, leaves, and tubers. If wet or damp weather continues after infection, the entire plant quickly decays. The disease can spread so rapidly that in a few days an apparently healthy field may be severely damaged.

The two types of chemical control used for late blight are protectant and systemic fungicides. Protectants are initially applied according to disease forecasting models and inoculum levels before row closure (i.e., before the vines touch across the rows). Subsequent protectant fungicide applications are then made every 7 to 21 days, depending on weather conditions and the occurrence of late blight. Systemic fungicides are tank mixed with a protectant to avoid resistance and improve efficacy. All systemic fungicides that are active against late blight are locally systemic, meaning the fungicides move from one leaf layer to another within a leaf, or move only a short distance in the plant. Local systemics are applied after the disease has been identified through a monitoring program. Protectant fungicides used for late blight management include chlorothalonil-based products (Bravo, Equus, Echo); ethylene-bis-dithiocarbamate (EBDC) products (like mancozeb sold as Dithane, Manzate, Penncozeb; maneb sold as Manex; and metiram sold as Polyram); triphenyltin hydroxide (Super Tin and Agri Tin); and the recently labeled fluazinam (Omega). Triphenyltin hydroxide compounds used singly do not perform as well as those used in combination with chlorothalonil or an EBDC product. When triphenyltin hydroxide is used in combination with chlorothalonil or an EBDC, the level of disease control is usually better than using chlorothalonil or an EBDC alone. Locally systemic fungicides used for late blight management include cymoxanil (Curzate), dimethomorph (Acrobat), zoxamide (Gavel), and propamocarb hydrochloride (Previcur). Copper-based fungicides (Kocide, Nucop) have some efficacy against late blight, but are not as effective as the standard protectants (chlorothalonil and EBDCs).

The protectant fungicides used for managing late blight, with the exception of fluazinam, are also effective in managing potato early blight, caused by *Alternaria solani* and *Alternaria alternata*. The locally systemic materials labeled for control of late blight are not effective against early blight. The most effective fungicide for managing early blight is the locally systemic azoxystrobin (Quadris). Azoxystrobin (Quadris) will also provide protection against late blight, but a higher rate is necessary. Sound agronomic practices such as proper plant nutrition, water management, proper pest management and avoidance of other plant stresses can also greatly reduce early blight severity. Copper-based sprays are not as effective as chlorothalonil- and EBDC-based products on early blight.

Pink rot caused by *Phytophthora erythroseptica* can often be found in the field before harvest. It is characterized by rotted tuber tissues that turn pink after exposure to air for twenty to thirty minutes. Tubers infected with the pink rot pathogen later become susceptible to the bacteria that cause soft rot decay. Good irrigation practices that maintain proper moisture content will help to minimize this disease. The only fungicide that is effective in controlling pink rot is the systemic fungicide mefenoxam (Ridomil Gold Bravo, Ridomil Gold Copper, Ridomil Gold MZ, and Flouronil). Mefenoxam-based products are applied at planting with some growers making a second application again two weeks later. Mefenoxam used to be very effective against late blight until mefenoxam-resistant strains of the late blight pathogen become predominant in the mid-1990s. All foliar-applied mefenoxam products are pre-packaged with a protectant such as chlorothalonil or mancozeb in order to provide foliar protection for late blight and early blight. Alternatives to mefenoxam are needed with the occurrence of mefenoxam-resistance in the pink rot populations in eastern Idaho.

Potato viruses important after emergence in the Pacific Northwest include potato leafroll virus (PLRV), tobacco rattle virus (TRV) (the cause of corky ringspot), PVX, PVA, and several strains of PVY. Simple contact between a healthy and an infected plant can spread PVX, PVY, and PVA mechanically. PVY and PVA, however, are far more likely to be spread by aphids. PLRV and TRV cannot be spread mechanically but rely on a vector for spread. Foliar viruses (PVY, PVX, PVA, PLRV) are managed principally through the use of certified seed potatoes. Purchase of certified seed is about the only management option for PVX and PVY while certified seed combined with use of systemic insecticides, in-season aphid scouting, and late-season aphicide applications when aphids are present are necessary for PLRV management. Management procedures for corky ringspot include use of certified seed and (most importantly) use of nematicides like oxamyl (Vydate) or soil fumigation.

A complex of organisms, including the fungus *Verticillium dahliae*, the nematode *Pratylenchus penetrans*, and the bacterium *Erwinia carotovora* causes potato early die. Tubers that are infected with *Verticillium dahliae* may have a discolored vascular ring at the stem end. Foliar symptoms resemble a mature senescing potato plant and include uneven chlorosis, yellowing between leaf veins that may turn brown, and vascular discoloration of the stem at its base. Potato early die is managed culturally by planting certified seed, using a balanced fertility plan, maintaining optimum soil moisture levels, using resistant varieties, and rotating crops (planting potatoes at the most once every three years). Chemical control is achieved by applying metam sodium (Vapam, Busan, Metam) through sprinkler irrigation systems or by shank-injection.

White mold caused by *Sclerotinia sclerotiorum* is another fungal foliar disease of potatoes. This fungus is also pathogenic on more than 350 different species of plants. Other important hosts are beans, peas, canola, and some of the common weeds associated with potato production like lambsquarter and pigweed. Cultural practices for managing this disease include long crop rotations (especially with non-susceptible hosts like grain) and good fertility management that reduces excessive vine growth. Proper irrigation is a critical factor in dealing with potential white mold problems. Only two fungicides, fluazinam (Omega) and iprodione (Rovral) have shown efficacy in controlling white mold. PCNB (Blocker) has shown some efficacy when mixed with iprodione (Rovral). These fungicides are all protectant in nature and should be applied before the disease has become well established in the field.

Powdery scab caused by *Spongospora subterranea* subsp. *subterranea* creates cosmetic defects that can lead to rejection in fresh market potatoes. This pathogen can also be a vector for the potato mop-top virus that, fortunately, has never been reported in North America. Currently, no fungicides are labeled for control of powdery scab.

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

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

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

Critical Needs for Management of Diseases in PNW Potatoes at Post-Emergence

Research

- Search for alternatives for pink rot and pythium management.
- Improve current and develop additional disease forecasting models.
- Improve fungicide deposition on potato stems.
- Investigate early blight and white mold to understand more about the diseases including how aggressive they are and what fungicides are effective against them.
- Develop effective management practices to combat *Erwinia* (stem soft rot).
- Investigate bacteria that cause stem soft rot.
- Determine how herbicide crop damage impacts disease occurrence and severity.
- Investigate differences between fungicide placement techniques vs. soil drench.
- Basic research directed at a better understanding of powdery scab.
- Learn more about pink eye—basic biology, cause, develop possible management strategies.
- Develop fungicide formulations for chemigation application.

Regulatory

- "Fast track" new chemicals to avoid resistance issues.
- Maintain tolerances for fungicides on potatoes.
- Improve inspections and enforce late blight and other diseases on greenhouse, garden tomato transplants, and other garden sources (international).
- Investigate late blight on organic farms (inoculum sources).

Education

- Conduct workshops on at-risk pesticides.
- Teach resistance-management strategies to maintain length of effective pesticides.
- Educate home gardeners, organic growers, and nursery operators on dangers of importing late blight.
- Educate growers on black dot identification.

Insects

Insects injure potatoes indirectly by transmitting pathogens and directly by feeding on roots, tubers, seed pieces, leaves, and stems. The two most important insect pests are the green peach aphid (GPA) and the Colorado potato beetle (CPB), with several others, such as the tuber flea beetle, of regional or occasional importance.

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

Potato processors and packers tolerate little to no net necrosis symptoms because consumers demand defect-free produce. Hence, the economic threshold that justifies foliar applications of insecticides for GPA is extremely low: one to three wingless GPA per 100 leaves; an alternative economic threshold for winged aphids is one aphid per plant. Conservative thresholds particularly are required for leafroll-susceptible potatoes that will be held in storage before they are marketed (because net necrosis symptoms can continue to worsen after harvest) as well as for potatoes grown for seed (because infected seed potatoes are the ultimate source by which aphids acquire leafroll virus). Low treatment thresholds complicate aphid-scouting programs by requiring impractically large sample sizes; literally hundreds of leaves must be inspected weekly at every field to detect needle-in-haystack densities of colonizing aphids and to estimate aphid population densities within statistical limits of precision. In practice, many growers apply foliar insecticides at first detection of aphids.

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

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

Systemic insecticides are frequently used in early-season potatoes for aphid control. Because long-season potatoes particularly are prone to net necrosis, producers of these varieties treat these crops with maximum label rates of systemic insecticides; many additionally apply foliar materials at an extremely low threshold. In the shorter-season areas of Idaho, such as the eastern Snake River Valley, the growing season is short enough that fewer total aphicide applications are required. In these areas, aphids tend to build up later in the year (August vs. July in the Columbia Basin of Washington and Oregon) and exist in the field for fewer weeks of the growing season (due to late arrival and earlier harvest).

Sometimes growers use cheaper products with a shorter period of residual control (e.g., phorate (Thimet) and carbofuran (Furadan)). Based on trials conducted in Idaho, Oregon, and Washington, imidacloprid-based products (Admire, Gaucho, and Genesis) and thiamethoxam-based products (Platinum) provide significant aphid control. Imidacloprid and thiamethoxam applied at planting will provide 80 or more days of residual control. Compared with many foliar-applied insecticides, soil-applied systemics have the advantage of reducing kill of beneficial predatory and parasitic insects that inhabit the plant canopy.

Foliar aphicides, which can be used in early-season potatoes, include methamidophos (Monitor), which has a label restriction of a maximum of four applications; pymetrozine (Fulfill), which only be applied two times during the growing season; endosulfan (Thiodan); imidachloprid (Provado); thiamethoxam (Actara); and cyfluthrin + imidacloprid (Leverage), which cannot be used if the field has been treated with imidacloprid (Admire, Genesis, Gaucho) or thiamethoxam (Platinum) during the current year. Cyfluthrin + imidacloprid (Leverage) has some rotational restrictions. One of the most significant is a one-year plant back restriction on onions. In years with high numbers of winged GPA, a management program that uses foliar insecticides applied in response to scouting is insufficient to prevent PLRV transmission in late-season Russet Burbank potatoes.

If aphid flights have been forecast, seed treatment insecticides are used. Some growers use soil insecticides which are applied at either planting time or layby. Application of aphicides for late-season potatoes begins just prior to the expected end of the period of residual control or "break" of the residual insecticides applied earlier. Foliar aphicides used in late-season potatoes include methamidophos (Monitor), which has a label restriction of a maximum of four applications; pymetrozine (Fulfill), which can only be applied two times during the growing season; and thiamethoxam (Actara), which has a label restriction of three ounces per season.

Although growers recognize the need to control aphids in all potato fields, many potatoes processed or packed directly from the field (i.e., early-season potatoes) receive minimal insecticides as cost-saving measures because these early-season varieties do not develop net necrosis symptoms as do late-maturing potatoes (e.g., Russet Burbank). Hence these early season crops can be a source of aphid infestation for other fields. A single, well-timed foliar application prior to development of winged aphids can aid in their control. Aphids need to be controlled until vines are dead or as close to vine-kill as possible while observing pre-harvest intervals on product labels.

Greenhouse-grown bedding plants are significant source of aphid infestation. Because insecticide resistance in GPA has been documented in greenhouses, PNW potato growers are concerned about this continual source of GPA infestation. Low levels of insecticide resistance in potatoes have been measured in Idaho and Washington, but no control losses due to resistance have been documented.

The method of pre-harvest desiccation of early-season potatoes can influence the formation and emigration of winged aphids. Most growers use broad-spectrum herbicides such as diquat (Reglone), paraquat (Boa, Gramoxone Extra), and glufosinate-ammonium (Rely). Sulfuric acid may also be used. All these chemical means are preferable to dehydration by withholding irrigation because they act immediately and so decrease the likelihood that aphids will develop winged adults that move to other fields at the end of the season. In contrast, desiccation of potatoes by withholding irrigation slowly dehydrates foliage and can trigger wing formation in aphids and stimulus for flight. Desiccation of potatoes by withholding irrigation should only be used as a last resort. If water management is used to desiccate the crop, it is critical that an effective aphicide such as pymetrozine (Fulfill) or methamidophos (Monitor) be used.

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

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

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

CPB in the PNW are still susceptible to most common insecticides. However, insecticide resistance was discovered in Idaho in the mid-1980s. Widespread and locally diverse esfenvalerate (Asana) and phosmet (Imidan) resistance was detected in all counties in southern and eastern Idaho in 1992. No resistance was detected to carbofuran (Furadan) or endosulfan (Thiodan). Resistance has the greatest potential to eliminate insecticides as useful tools in CPB management.

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

In fields treated for aphids with regular applications of methamidophos (Monitor), imidacloprid (Provado), or thiamethoxam (Actara), CPB will also be controlled. Spinosad (Success), abamectin (Agri-Mek), phosmet (Imidan), imidacloprid (Provado), thiamethoxam (Actara), and cyfluthrin + imidacloprid (Leverage) are listed for CPB in the IPM guidelines. Many of the products are much more expensive than the pyrethroids, so many growers still opt for the cheaper, more broad-spectrum materials. This choice can lead to secondary outbreaks of mites and/or aphids by interfering with natural enemies of these pests. Phorate (Thimet) applied at planting time and carbofuran (Furadan) applied just prior to emergence in a banded spray are used for early control of CPB in Idaho. Carbofuran (Furadan) should not be used in two successive years at the same site to prevent CPB resistance, which has been observed in other potato growing regions.

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

The only two miticides registered on potatoes are propargite (Comite, Omite) and abamectin (Agri-Mek). Propargite (Comite, Omite) is by far the most commonly used material partly because it can be applied by air. Abamectin (Agri-Mek) requires application with 20 gallons of water/acre – an unfeasible situation by air. Additionally, abamectin (Agri-Mek) cannot be applied by chemigation and most growers are reluctant to apply miticides by ground. Neither product will provide full control or serve as a rescue treatment once mite populations reach outbreak levels. Miticides need to be applied before populations reach two mites per compound leaf.

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

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

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

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

Management of insecticide resistance is an important issue in potatoes. According to the *2002 Integrated Pest Management Program for Insects in Pacific Northwest Potatoes,* "The two most significant insect pests of potatoes in the world, Colorado potato beetle and green peach aphid have developed resistance to virtually every insecticide used for their control. While the Pacific Northwest has largely escaped this problem, the development of insecticide resistance in these pests is still an issue that the potato industry needs to be prepared for. Once resistance is established in a population to an insecticide, the utility of this product is largely lost. Avoidance of resistance or resistance management is the best means to preserve the effectiveness of potato insecticides. In 2002, PNW potato growers will have access to four planting products, imidacloprid (Admire, Genesis, Gaucho) and thiamethoxam (Platinum), and three foliar products, imidacloprid (Provado), cyfluthrin + imidacloprid (Leverage) and thiamethoxam (Actara). All seven belong to the same class of chemistry, the neonicotinoids. Due to certain characteristics of this pesticide class and the propensity of CPB and GPA to develop resistance, there exists the potential for development of resistance to the entire class if the products are not used carefully."

Critical Needs for Management of Insects in PNW Potatoes at Post-Emergence

Research

- ❖ Investigate the naturally occurring virus of GPA as an alternative biological control. Consider stability and transmission characteristics that would allow its adaptation for control of GPA.
- ❖ Develop effective late-season GPA control.
- ❖ Study naturally occurring parasitoids of aphids.
- ❖ Investigate beneficial insects in potato cropping systems.
- ❖ Create a cost-effective GPA detection system that would detect first occurrence of the aphids.
- ❖ Increase regional resistance monitoring for CPB and GPA.
- ❖ Investigate secondary pest infestations occurring after broad-spectrum insecticide applications.
- ❖ Investigate insecticide efficacy on a commercial field scale.
- ❖ Develop region-wide monitoring system of GPA, including a website, a hotline, etc.
- ❖ Develop research-based scouting procedures and predictive forecasting models for lepidopteran worms and establish economic thresholds based on these procedures and models.
- ❖ Study multiple pest interactions, i.e., vegetation management for pest species and source of natural enemies (insectary crops).
- ❖ Continue area wide IPM. Support cooperative decisions made at regional level—CPB and GPA.
- ❖ Increase knowledge of Bt use for control of worm populations given that neonicotinoids do not work. Look at the use of narrow-spectrum carbamates such as oxamyl (Vydate).
- ❖ Study mite-resistant clones.

Regulatory

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

Education

- ❖ Educate growers in resistance management.
- ❖ Educate growers about beneficial insects
  - How to promote beneficial insects
  - How chemicals affect beneficial insects.

Weeds

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

Herbicides used for control of most broadleaf and some grassy weeds after the potato crop has emerged include EPTC (Eptam), pendimethalin (Prowl,), s-metolachlor (Dual), rimsulfuron (Matrix), metribuzin (Sencor, Lexone), and trifluralin (Treflan). Use of s-metolachlor (Dual) post emergence is limited because of unacceptable crop injury. S-metolachlor (Dual) is used for yellow nutsedge control with some crop damage expected. EPTC (Eptam), pendimethalin (Prowl), s-metolachlor (Dual), and trifluralin (Treflan) will not control emerged weeds. These herbicides are commonly included in 2- and 3-way tank mixetures and many are applied with chemigation. Trifluralin (Treflan) can be applied after potatoes have fully emerged, and must be incorporated without completely covering emerged potato plants with treated soil. EPTC (Eptam) also must be incorporated after application. Sethoxydim (Poast), and clethodim (Select) are used for control of grassy weeds postemergence. All herbicides except sethoxydim (Poast), rimsulfuron (Matrix), and clethodim (Select) must be applied before potatoes reach 4-6 inches in height.

Critical Needs for Management of Weeds in PNW Potatoes at Post-Emergence

Research

- ❖ Develop herbicides especially for post-crop-emergence.
- ❖ Investigate critical weed interference period (the time when weeds absolutely must be controlled to prevent yield loss).

- Document yield losses associated with harvest interference with weeds.
- Investigate weed/pest interactions as reservoirs for disease and hosts for insects and nematodes and sources of natural enemies for pest species and soil-borne fungi.
- Investigate herbicide resistance management in a cropping systems approach.
- Develop GM potatoes for herbicide tolerance.
- Conduct a weed survey.
- Continue research on the relationship between hairy nightshade and green peach aphid, potato leaf roll, and tobacco rattle virus.
- Investigate chemigation with sprinkler incorporation of herbicides.
- Investigate enhanced degradation of EPTC (Eptam).

Regulatory

- Regulate invasive weed species.
- Work with EPA in addressing FQPA issues to provide realistic and commonsense risk assessment data in order to avoid loss or cancellation of commonly used/needed herbicides.
- Identify minor use needs and translate needs to IR-4 priority and/or relationship with registrant to influence their priority lists.
- Harmonize herbicide registrations and labels.

Education

- Educate growers and extension educators so they are the first to identify new invasive weed species.
- Increase technology transfer about new weeds, herbicide resistance, critical weed interface periods, and benefit/risk analysis of herbicide use.
- Develop online weed management recommendations.
- Develop online weed identification website.
- Develop online databases that include search functions for pesticides by pest type.

VINE-KILL

Killing potato vines before harvest is a common practice in many areas of the Pacific Northwest. Killing vines two to three weeks before harvest allows the stolons to loosen from the tubers and hastens tuber maturity and "skin set." It takes 18 to 21 days for tuber skins to mature once the skin set process has started. A tough, fully mature skin provides excellent disease and bruise protection, which helps protect the tuber from some tuber-rotting organisms (see harvest section).

The mature skin is also crucial for providing a quality crop during harvesting and storage. Since 90 percent of potatoes are stored (either on-farm, by processors, or by fresh-pack shippers), minimizing storage loss is very important economically. Mature tubers lose less water during storage, are more resistant to skinning, generally have less tuber decay, and are more resistant to shatter bruise during harvest.

In areas of the Pacific Northwest where the growing season is particularly short and the ideal harvest window is minimal, vine killing is accomplished by using chemical desiccants or mechanical choppers to hasten tuber maturity so harvest can be completed before freezing temperatures damage tubers in the soil. The use of desiccants can also help control late-germinating weeds, and reduce weed biomass that may interfere with harvest.

Mechanical vine-killing techniques may consist of rolling the vines with weighted tires to crush the vines and open the crop canopy to aid in vine death or by using a flail-type mower to chop the vines. A combination of vine-kill methods may also be used. For example, some growers may chop the vines while pulling a roller behind the chopper to seal the ground followed by a chemical vine-killing material applied two to three days later. Chemical desiccants used include glufosinate-ammonium (Rely), diquat (Reglone), paraquat (Boa, Gramoxone Extra) not used on potatoes to be stored, and sulfuric acid.

Critical Needs for Management of Vine-Kill in PNW Potatoes

Research

- Investigate vine-kill products on late-season weed control and weed seed kill.
- Investigate harvesting and storage of non vine-killed potatoes.
- Compare rapid vs. slow vine-kill materials and risks for potato virus contamination.
- Investigate virus disease spread with regard to mechanical vine-kill.
- Determine effect of vine-kill products on skin set and stem-end discoloration.
- Develop management strategies for control of late blight under slow vine-kill conditions.
- Investigate transmission of late blight under green vines. Determine risk potential of tuber late blight and early blight.

Regulatory

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

Education

- ❖ None.

HARVEST

For pest management practices during harvest, the challenge is minimizing the amount of diseased tubers being placed into storage. Fusarium dry rot and Pythium leak are two important diseases that can cause storage rot problems. Each requires a wound to infect the tubers. Pink rot may also be able to infect tubers that are wounded. Minimizing shatter bruise (broken skin or periderm of the tuber) helps reduce the amount of infection from those diseases requiring a wound to infect. Growers also try to minimize the amount of tuber skinning, which is when the skin is scuffed from the tuber flesh. To minimize bruising, growers strive to have the proper soil moisture, tuber hydration, tuber temperature, and skin set.

Tubers are allowed to remain in the soil for two to three weeks after vine-kill so skins mature, resulting in more mature skins and less skinning damage.

A light irrigation is applied prior to harvesting to condition the soil so clods will break apart during harvest. Timing of the pre-harvest irrigation depends on soil type. Sandy soils can be irrigated closer to harvest than soils containing more silt or clay.

Tuber hydration level (whether a tuber is hydrated and crisp (turgid) or dehydrated and limp (flaccid) influences the amount of bruising. Tuber hydration is, in turn, influenced by irrigation practices just prior to harvesting. The timing of an irrigation to hydrate tubers depends on the desired tuber hydration level, potato variety, and soil type.

Compounding the difficulty of managing shatter bruise is the fact that another bruise type, blackspot bruise (cells just beneath the tuber skin turn black although the skin is not broken) will result in loss of quality of the crop. Dehydrated tubers are more prone to blackspot bruise, while hydrated tubers tend to exhibit more shatter bruise. There is a point between hydrated and dehydrated that results in the least amount of total tuber bruising, but this point also depends on tuber pulp temperature. Potato varieties have varying degrees of susceptibility to both shatter and blackspot bruising.

Temperature also affects bruising. Ideally, tubers are harvested with a pulp temperature of 50 to 60 F.Generally, cold tuber pulp temperatures increase both blackspot and shatter bruise. Cold, hydrated tubers tend to shatter bruise more readily, whereas warm, dehydrated tubers blackspot bruise more easily. Tubers with warm pulp temperatures may not bruise as readily, but warm tubers are at risk of rot problems in storage. Not all varieties can be managed the same way to achieve minimum bruising.

Tuber pulp temperature is directly influenced by soil temperature. The amount of water, soil organic matter content, slope, and aspect of a field may all influence soil temperature.

Critical Needs for Harvest of PNW Potatoes

Research

- ❖ Develop a harvester that destroys small potatoes.
- ❖ Investigate cultivar differences and vine-killing in blackspot bruise management.
- ❖ Investigate irrigation management on cultivars and bruise.

Regulatory

- ❖ None.

Education

- ❖ Educate growers about harvest management for controlling volunteer potatoes.

POST-HARVEST

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

The primary method to control sprouting in storage is use of chlorpropham (CIPC). CIPC inhibits sprout development by interfering with cell division. Since CIPC interferes with wound healing, it must be applied after the wound-healing period (two to three weeks) but before dormancy break or initiation of sprout growth. Commercial applicators apply CIPC as an aerosol formulation to bulk potatoes in storage. CIPC as a liquid concentrate or a solid product liquefied by heating is pumped into the aerosol-generator. These liquid CIPC formulations are heated into an aerosol that can be delivered into the potato pile by the circulating air system in the storage facility. The rate may vary depending on the variety, storage temperature, and the length of intended storage. Applications of CIPC as an emulsifiable concentrate are applied directly to washed potatoes prior to packaging. Maleic hydrazide (MH-30) is sometimes applied to potato foliage during the growing season. Substituted naphthalene, 1,4-dimethylnaphthalene (1,4-Sight) is sometimes applied as a sprout suppressor in storage.

This product most likely suppresses sprouts by hormonal action and gives approximately 30 days of control. Other products available for sprout control in storage are chemicals that physically damage the sprout and therefore need to be applied on a regular or continuous basis. Those products include eugenol (Biox – A) and spearmint and peppermint oils. Cost, application methods, and long-term efficacy are considered by growers. There is currently no alternative to CIPC for long-term sprout suppression.

Very few post-harvest fungicides or disinfectants are available to the potato industry. Due to Fusarium dry rot resistance to thiabendazole (Mertect 340-F), use of the product is not recommended and therefore limited. No other post-harvest fungicide is labeled. General biocides or disinfectants available include hydrogen peroxide and peroxyacetic acid mixtures (Oxidate and Tsunami), sodium hypochlorite, and calcium hypochlorite. These are applied to potatoes going into storage. Potatoes must be rinsed with potable water before use. Oxidate can also be applied to potatoes in storage through the humidification system. A Section 18 registration was granted by the USEPA for the use of a chlorine dioxide aqueous solution applied to potatoes going into storage and through the humidification system. Application methodology problems and the high organic load associated with storing potatoes reduce the efficacy of these disinfectants. No disinfectant will stop an established disease infection.

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

Critical Needs of PNW Potatoes at Post-Harvest

Research

- Develop post-harvest volunteer control for seed potatoes (MH 30 not an option for seed potatoes).
- Investigate volunteer potato control in other rotational crops.
- Develop chemicals for sprout suppression, any method of application.
- Address concerns about post-harvest chemicals and foreign market tolerances (see Regulatory, below).
- Investigate sprout suppression for seed potatoes.

- Investigate the effect of storage temperature on nematode development and damage in storage.
- Improve management of Fusarium dry rot and silver scurf.
- Develop effective post-harvest fungicides and bactericides.
- Determine efficacy of lower rates of CIPC in conjunction with other chemicals.
- Investigate weed seed banks contributions in potato cropping systems.
- Determine effect of herbicide carryover to rotational crops; new herbicides.
- Determine the optimum temperature for potato storage to prevent further nematode development and reproduction.

Regulatory

- Develop a sprout inhibitor chemical that meets tolerances for foreign markets.
- Maintain tolerance for CIPC until viable economic alternative is available.
- Hasten registration of Amplify (DIPN).

Education

- Educate growers on storage management practices (humidity, temperatures, air flow).
- Educate growers on seasonal effects on storage.

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Activity Tables for the Treasure Valley and Eastern Oregon Region

Cultural Activities Profile for PNW

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

Note: Information based on grower and pest control advisor experience.

Pest Management Activities and Crop Monitoring Profile for PNW Potatoes

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

Note: Information based on grower and pest control advisor experience.

Seasonal Pest Occurrence in PNW Potatoes

Activity Tables for the Treasure Valley and Eastern Oregon Region

	J	F	M	A	M	J	J	A	S	O	N	D
INSECTS/MITES												
Green peach aphids						-------	-------	-------	-------			
Colorado potato beetles				-------	-------	-------	-------	-------	-------			
Wireworms			-------	-------	-------	-------						
Symphylans			-------	-------	-------							
Spider mites							-------	-------	-------			
DISEASES												
Seed piece decay			-------	-------								
Early blight					-------	-------	-------	-------	-------			
Late blight			seed	seed		-------	-------	-------	-------			
Early dying			seed	seed			-------	-------	-------			
Potato leaf roll virus				-------	-------	-------	-------					
Pink rot (+ storage)	-------	-------	-------	-------	-------	-------	-------	-------	------	-------	-------	-------
Pythium leak									-------	-------		
Fusarium dry rot	-------	-------	-------	-------					-------	-------	-------	-------
Silver scurf	-------	-------	-------	-------						-------	-------	-------
Bacterial soft rot					-------	-------	-------					
White mold							-------	-------	-------			
Rhizoctonia stem canker (Black scurf)				-------	-------	-------	-------	-------	-------	-------		
WEEDS												
Nightshade, hairy			-------	-------	-------	-------	-------	-------	------			
Kochia			-------	-------	-------	-------	-------	-------	------			
Pigweed, redroot			-------	-------	-------	-------	-------	-------	------			
Grasses			-------	-------	-------	-------	-------	-------	------			
NEMATODES												
Root-knot nematode			-------	-------	-------	-------	-------	-------	------	-------		
Root-lesion nematode			-------	-------	-------	-------	-------	-------	------	-------		
Stubby-root nematode			-------	-------	-------	-------	-------	-------	------	-------		
VERTEBRATES												
Voles							-------	-------	-------	-------	-------	

Activity Tables for the Columbia Basin Region

Cultural Activities Profile for PNW

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

Note: Information based on grower and pest control advisor experience.

Pest Management Activities and Crop Monitoring Profile for PNW Potatoes

Activity	J	F	M	A	M	J	J	A	S	O	N	D
MH-30						-------	-------	-------	-------			
Insecticide app.		-------	-------	-------	-------	-------	-------	-------	-------			
Herbicide app.		-------	-------	-------	-------	-------	-------	-------				
Fungicide app.		-------	-------	-------	-------	-------	-------	-------	-------			
Fumigants	-------	-------	-------	-------				-------	-------	-------	-------	-------
Aerial monitoring					-------	-------	-------	-------				
Soil and water analysis	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Soil sampling for nematodes	-------	-------	-------	-------				-------	-------	-------	-------	-------
Weed surveys			-------	-------	-------	-------	-------	-------				
Monitor for wireworms												
Keep weather records	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Petiole nutrient analysis				-------	-------	-------	-------	-------	-------			
Irrigation scheduling			-------	-------	-------	-------	-------	-------	-------			
Monitor soil moisture		-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	
Monitor soil temperature		-------	-------	-------						-------	-------	
Monitor weed emergence			-------	-------	-------	-------	-------	-------				
Monitor for aphids					-------	-------	-------	-------	-------			
Monitor for early blight and late blight					-------	-------	-------	-------	-------			
Monitor canopy moisture, temperature and humidity				-------	-------	-------	-------	-------	-------			
Monitor temperature and humidity			-------	-------	-------	-------	-------	-------	-------	-------		

Note: Information based on grower and pest control advisor experience.

Seasonal Pest Occurrence in PNW Potatoes

Activity Tables for the Columbia Basin Region

	J	F	M	A	M	J	J	A	S	O	N	D
INSECTS/MITES												
Green peach aphids					-------	-------	-------	-------	-------			
Colorado potato beetles				-------	-------	-------	-------	-------	-------			
Wireworms		-------	-------	-------	-------	-------	-------	-------	-------			
Spider mites						-------	-------	-------				
Thrips						-------	-------	-------				
Lepidoptera larvae (worms)				-------	-------	-------	-------	-------	-------			
Seed corn maggot		-------	-------	-------	-------							
DISEASES												
Seed piece decay		-------	-------	-------	-------							
Early blight					-------	-------	-------	-------	-------			
Late blight						-------	-------	-------	-------	-------		
Early dying			-------	-------	-------	-------	-------	-------	-------	-------		
Potato leaf roll virus						-------	-------	-------	-------	-------		
Pink rot	-------	-------				-------	-------	-------	-------	-------	-------	-------
Pythium leak	-------	-------				-------	-------	-------	-------	-------	-------	-------
Fusarium dry rot	-------	-------				-------	-------	-------	-------	-------	-------	-------
Silver scurf	-------	-------	-------				-------	-------	-------	-------	-------	-------
Bacterial soft rot	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
White mold					-------	-------	-------	-------				
Rhizoctonia stem canker (Black scurf)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Powdery scab						-------	-------	-------				
Bacterial stem rot						-------	-------	-------				
Common scab						-------	-------	-------	-------	-------		
Corky ring rot				-------	-------	-------	-------	-------	-------	-------		
Aphid borne viruses				-------	-------	-------	-------	-------	-------	-------		
WEEDS												
Nightshade, hairy + black				-------	-------	-------	-------	-------	------			
Kochia		-------	-------	-------	-------	-------	-------	-------	------			
Pigweed, redroot				-------	-------	-------	-------	-------	------			
Grasses				-------	-------	-------	-------	-------	------			
Lambsqarter			-------	-------	-------	-------	-------	-------	-------			
Russian thistle		-------	-------	-------	-------	-------	-------	-------	-------			
Nutsedge					-------	-------	-------	-------	-------			
Cutleaf nightshade				-------	-------	-------	-------	-------	------			
Volunteer potatoes	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
NEMATODES												
Root-knot nematode	-------	-------	-------	-------	-------	-------	-------	-------	------	-------	-------	-------
Root-lesion nematode	-------	-------	-------	-------	-------	-------	-------	-------	------	-------	-------	-------
Stubby-root nematode	-------	-------	-------	-------	-------	-------	-------	-------	------	-------	-------	-------

Activity Tables for the Western Oregon and Washington Region (West of the Cascades)

Cultural Activities Profile for PNW

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

Note: Information based on grower and pest control advisor experience.

Pest Management Activities and Crop Monitoring Profile for PNW Potatoes

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

Note: Information based on grower and pest control advisor experience.

Seasonal Pest Occurrence in PNW Potatoes

Activity Tables for the Western Oregon and Washington Region (West of the Cascades)

	J	F	M	A	M	J	J	A	S	O	N	D
INSECTS/MITES												
Green peach aphids					-------	------	------	-------				
Colorado potato beetles												
Wireworms				-------	------	------						
Symphylans				-------	------	------						
DISEASES												
Seed piece decay				-------	------	------						
Early blight							-------	------	------			
Late blight						-------	------	------	-------	------		
Early dying								-------	------			
Potato leaf roll virus						-------	------	------				
Pink rot								-------	------			
Pythium leak								-------	------			
Fusarium dry rot				-------	------	------						
Silver scurf									-------	------	------	
Bacterial soft rot	-------	------	------	-------	------	------					-------	------
White mold								-------	------			
Rhizoctonia stem canker (Black scurf)					-------	------	------	-------				
WEEDS												
Nightshade, hairy							-------	------	------	-------		
Kochia									-------	------		
Pigweed, redroot									-------	------		
Grasses									-------	------		
NEMATODES												
Root-knot nematode												
Root-lesion nematode												
Stubby-root nematode												
VERTEBRATES												
Voles												

Activity Tables for the South Eastern Idaho Region

Cultural Activities Profile for PNW

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

Note: Information based on grower and pest control advisor experience.

Pest Management Activities and Crop Monitoring Profile for PNW Potatoes

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

Note: Information based on grower and pest control advisor experience.

Seasonal Pest Occurrence in PNW Potatoes

Activity Tables for the South Eastern Idaho Region

	J	F	M	A	M	J	J	A	S	O	N	D
INSECTS/MITES												
Green peach aphids						-------	------	------	-------			
Colorado potato beetles						-------	------	------				
Wireworms					-------	------	------	-------	------			
Grasshoppers						-------	------	------				
Crane Fly						-------	------	------				
Leafhoppers							-------	------				
Loopers						-------	-------					
DISEASES												
Seed piece decay				-------	------	------						
Early blight						-------	------	------	-------			
Late blight				seed	seed	------	-------	------	------	-------		
Early dying				seed	seed			-------	------			
Potato leaf roll virus							-------	------	-------	-------		
Pink rot								-------	------	------	-------	------
Pythium leak									-------	------	------	
Fusarium dry rot										-------	------	------
Silver scurf	-------	------	------								-------	------
Bacterial soft rot	-------	------	------	-------	------	------	-------	------	------	-------	------	------
White mold							-------	------	------			
Rhizoctonia stem canker (Black scurf)					-------	------	------	-------	------			
Pink eye								-------	------	------		
WEEDS												
Nightshade, hairy					-------	------	------	-------	------			
Kochia				-------	------	------	-------	------	------			
Pigweed, redroot					-------	------	------	-------	------			
Grasses					-------	------	------	-------	------			
Volunteer grain					-------	------						
Common lambsquarter					-------	------	------	-------	------			
Wild oats					-------	------	------					
Green foxtail					-------	------	------					
NEMATODES												
Root-knot nematode					-------	------	------	-------	------	------		
Root-lesion nematode					-------	------	------	-------	------	------		
Stubby-root nematode					-------	------	------	-------	------	------		
VERTEBRATES												
Voles								-------	------	------		

Activity Tables for the Eastern Idaho Region

Cultural Activities Profile for PNW

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

Note: Information based on grower and pest control advisor experience.

Pest Management Activities and Crop Monitoring Profile for PNW Potatoes

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

Note: Information based on grower and pest control advisor experience.

Seasonal Pest Occurrence in PNW Potatoes

Activity Tables for the Eastern Idaho Region

	J	F	M	A	M	J	J	A	S	O	N	D
INSECTS/MITES												
Green peach aphids						-------	------	------	-------			
Colorado potato beetles						------	------	-------	------			
Wireworms				-------	------	------	-------	------	------			
DISEASES												
Seed piece decay				-------	------	------						
Early blight						-------	------	------				
Late blight				seed	seed		-------	------	------			
Early dying				seed	seed		-------	------				
Potato leaf roll virus							-------	------	-------	-------	-------	-------
Pink rot								-------	------	-------	-------	-------
Pythium leak	-------	------	------	-------	------	------				-------	------	------
Fusarium dry rot	-------	------	------	-------	------	------				-------	------	------
Silver scurf	-------	------	------	-------	------					-------	------	------
Bacterial soft rot	-------	------	------	-------	------	------	-------				-------	------
White mold							-------	------				
Rhizoctonia stem canker (Black scurf)					-------	------	------					
WEEDS												
Nightshade, hairy					-------	-------	-------	-------	-------	-------		
Kochia					-------	-------	------	-------				
Pigweed, redroot					-------	-------	-------					
Grasses					-------	-------	-------	-------	-------	-------		
NEMATODES												
Root-knot nematode			-------	------	------	-------	------	-------	-------	-------		
Root-lesion nematode			-------	------	------	-------	------	-------				
Stubby-root nematode			-------	------	------	-------	------	-------				
VERTEBRATES												
Voles							-------	------	------			

Activity Tables for the Magic Valley Region

Cultural Activities Profile for PNW

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

Note: Information based on grower and pest control advisor experience.

Pest Management Activities and Crop Monitoring Profile for PNW Potatoes

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

Note: Information based on grower and pest control advisor experience.

Seasonal Pest Occurrence in PNW Potatoes

Activity Tables for the Magic Valley Region

	J	F	M	A	M	J	J	A	S	O	N	D
INSECTS/MITES												
Green peach aphids						------	------	------	------			
Colorado potato beetles						---	------	------				
Wireworms			----	------	------	------	------	------	----			
Loopers / Armyworms						------	------	------				
DISEASES												
Seed piece decay				------	------	------						
Early blight							------	------	------			
Late blight				seed	seed		------	------	------			
Early dying				seed	seed		------	------	------			
Potato leaf roll virus							------	------	------	-------	-------	-------
Pink rot								---	------	------	------	-------
Pythium leak								---	------	------	------	------
Fusarium dry rot	------	------	------	------				------	------	------	------	------
Silver scurf	------	------	------	------	------	------						
Bacterial soft rot	------	------	------	------	------	------	------	------	------	------	------	------
White mold							------	------				
Rhizoctonia stem canker (Black scurf)			------	------	------	------	------	------	------			
Black dot							------	------	---			
WEEDS												
Nightshade, hairy					------	------	------	------	------	------		
Kochia				------	------	------	------	------	------			
Pigweed, redroot					------	------	------	------	------			
Grasses				------	------	------	------	------	------			
Quackgrass				------	------	------	------	------	------	---		
NEMATODES												
Root-knot nematode			------	------	------	------	------	------	------			
Root-lesion nematode			------	------	------	------	------	------	------			
Stubby-root nematode			------	------	------	------	------	------	------			
VERTEBRATES												
Voles							------	------	------	------		

Activity Tables for the Alaska Region

Cultural Activities Profile for PNW

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

Note: Information based on grower and pest control advisor experience.

Pest Management Activities and Crop Monitoring Profile for PNW Potatoes

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

Note: Information based on grower and pest control advisor experience.

Seasonal Pest Occurrence in PNW Potatoes

Activity Tables for the Alaska Region

	J	F	M	A	M	J	J	A	S	O	N	D
INSECTS/MITES												
Green peach aphids												
Colorado potato beetles												
Wireworms					------	------						
Grasshoppers						------	------	------				
DISEASES												
Seed piece decay					------	------						
Early blight							------	------	------			
Late blight								------	------			
Early dying												
Potato leaf roll virus												
Pink rot								------	------			
Pythium leak								------	------			
Fusarium dry rot	------	------	------	------	------	------	------	------	------	------	------	------
Silver scurf	------	------	------	------	------	------	------	------	------	------	------	------
Bacterial soft rot	------	------	------	------	------	------	------	------	------	------	------	------
White mold							------	------	------			
Rhizoctonia stem canker (Black scurf)							------	------	------			
Common scab						------	------	------	------			
Pink eye								------	------	------		
Powdery scab						------	------	------				
WEEDS												
Nightshade, hairy												
Kochia												
Pigweed, redroot												
Quackgrass					------	------	------					
Pineapple weed					------	------	------					
Lambsquarter					------	------	------					
Chickweed					------	------	------					
P sowthistle					------	------	------					
Hempnettle					------	------	------					
Corn spurry					------	------	------					
NEMATODES												
Root-knot nematode												
Root-lesion nematode												
Stubby-root nematode												
VERTEBRATES												
Voles								------	------			

Efficacy Tables for Pest Management Tools

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

Insecticides Registered on Potatoes

MANAGEMENT TOOL	GPA	CPB	WRW	SYM	SPM	LEP	LYG	OTHER		Comments
1,3-dichloropropene (Telone II, Telone C-17, Telone C-35)			G	X						Telone C-17 and Telone C-35 are mixtures with chloropicrin.
Abamectin (Agrimek)					P					Application methods impractical. Priced too high.
Aldicarb (Temik)	G	G			G			aphids (G)		
Azinphos-methyl (Guthion)		G								
Carbaryl (Sevin)		F				G		beetles (G), grasshoppers (G)		Excellent knock down. No residual. Bee concerns. One of few post-plant options.
Carbofuran (Furadan)	P	G	P			F		aphids(P), beetles (G)		
Chloropicrin (Telone C-17, Telone C-35)			G							Telone C-17 and Telone C-35 are mixtures with 1,3 dichloropropene.
Cryolite (Kryocide, Prokil)		F								
Cyfluthrin (Baythroid)	F-P	E				G		beetles (G)		Very cost effective. Not effective (good enough) for seed protection.
Diazinon (WA-24c)				F-P						
Dimethoate (Cygon)	F-P							aphids (F)		Low efficacy for GPA.
Disulfoton (Di-Syston)	G	F						aphids, beetles		
Endosulfan (Thiodan, Phaser)	F-G	G								Short period of efficacy.
Esfenvalerate (Asana)	P	E				E	E	aphids (P), beetles (G)		Resistance problem.
Ethoprop (Mocap)			G-F	G						Critical for WRW control. Not good on high populations.
Imidacloprid (Admire, Genesis, Gaucho)	E	E	F					aphids (P), beetles (G)		Use is expanding. More research on WRW needed.
Malathion (Cythion)	P							various insects		Low efficacy.
Malathion + methoxychlor (Malathion Methoxychlor Spray)										
Metam potassium (K-Pam)			G	G						Contact only.
Metam sodium (Vapam)			G	G						Contact only.

Insecticides Registered on Potatoes (page 2)

MANAGEMENT TOOL (continued)	GPA	CPB	WRW	SYM	SPM	LEP	LYG	OTHER		Comments
Methamidophos (Monitor)	E	F				G	F	aphids (G), beetles (G)		A very reliable aphicide for GPA. Critical for seed production.
Methomyl (Lannate)	F							various insects (G-P)		Limited use currently.
Methoxychlor		P				F		beetles (F)		Blister beetles rarely a pest. Limited use currently.
Methyl parathion (Declare, Penncap-M)		F-G								
Oxamyl (Vydate)	G	D-F			F-P		F	aphids (G)		Works on in-season nematodes.
Permethrin (Pounce, Ambush)		E-G				E	E	potato aphid (F), beetles (F)		Not effective for GPA. Resistance problem.
Phorate (Thimet)	F-G	G	F					beetles (G)		
Phosmet (Imidan)		G								May become more important in IPM.
Propargite (Comite, Omite)					F					
Sulfur (Micro Sulf)					F-P- red spider mite					
Alternative Insecticides										
Spinosad (Success)		G-E				G		thrips (G)		
Thiamethoxam (Platinum, Actara)(WA-24c)	E	E						aphids (E), beetles (E)		Newly registered - WA-24c is for Actara 3.0 oz rate for aphids.
Pymetrozine (Fulfil)	G-E							aphids (G-E)		Newly registered. Promising for shorter season crop. Unique mode of action.
Biological Insecticides										
Azadirachtin (Agroneem, Ecozin, Neemix)								various insects		
Bacillus thuringiensis spp. *tenebrionis* (Novodor)		G								Priced too high.
Bacillus thuringiensis spp. *aizawai* (Agree, Ketch, Mattch, XenTari)						G				

Insecticides Registered on Potatoes (page 3)

MANAGEMENT TOOL (continued)	GPA	CPB	WRW	SYM	SPM	LEP	LYG	OTHER		Comments
Bacillus thuringiensis spp. *Berliner (BT 320 Sulfur 25 Dust)*								cabbage looper (G)		
Bacillus thuringiensis strain EG7841(both *aizawai* and *kurstaki* toxins)(Crymax)										
Beauvaria bassiana (Mycotrol)								various insects		
Cryolite (Na aluminofluoride) (Kryocide)		G			G					
Jojoba oil (Erase ECO)								whiteflies (F-G)		
Neem oil (Trilogy)					F					
Potassium salts of fatty acids (M-Pede)								soft-bodied arthropods		
IPM and Cultural Control										
Transgenic varieties		E								
Resistant varieties	X									
Use certified seed	F									
Growers physically examine leaves	G	G			G					
Scout fields	E	E			E					
Use of economic thresholds	F	E								
Rotate to non-host crops 3 out of 4 years										
Pipeline materials and possible biologicals										
Bifenazate (Acrimite)					X					Not listed by IR-4, but in trials in WA.
Deltamethrin (Decis)						X		beetles, bugs		"pending"
Etoxozole (Baroque, Zoom)					X					Not listed by IR-4, but in trials in WA.
Fipronil (Regent)			G					broad spectrum		"potential"
IKI 220								aphids		"potential"
Lufenuron (Match)						X		beetles, thrips		"potential"

Insecticides Registered on Potatoes (page 4)

MANAGEMENT TOOL (continued)	GPA	CPB	WRW	SYM	SPM	LEP	LYG	OTHER		Comments
Novaluron (Rimon)						X		beetles, aphids?		"potential"
Tebupirimphos (combined with cyfluthrin) (Aztec)		G	G-E							Not listed by IR-4, but in trials in WA.
Tefluthrin (Force)			G-E					soil insects		Not listed by IR-4, but in trials in WA.
Thiacloprid (Calypso, Alanto)								broad spectrum		"potential"
Bifenthrin (Capture)			F							
Biological										
Bacillus Sphaericus (Valent)								??		"potential"
Metarhizium anisopliae (Taerain)										"potential"

GPA= green peach aphid, CPB= Colorado potato beetle, WRW= wireworm, SYM= symphylans, SPM= Spider mites, LEP= Lepidoptera, LYG= *Lygus* .

Efficacy rating symbols: E=Excellent (90-100% control), G=Good (80-90% control), F=Fair (70-80% control), P=Poor (<70% control), ?=no data but suspected of being efficacious, X=no rating given.
(s) = secondary pest outbreaks
(c) = tank mix
(r) = regionality differences
(rs) = resistance

Efficacy Tables for Pest Management Tools

This table is a compilation of information concerning the efficacy of various compounds and practices on potato weed pests.

Weeds	EPTC (Eptam)	metolachlor (Dual)	trifluralin (Treflan)	pendimethalin (Prowl)	metribuzin (Sencor)	sethoxydim (Poast)	rimsulfuron (Matrix) Preemergence	rimsulfuron (Matrix) Postemergence	clethodim (Select)	To be registered Sonalan	To be registered Outlook
Barley, volunteer	G-F	------	P	------	P	G	G	G	G	------	------
Barnyardgrass	G	G	G	G	F	G*	G	G	G	G	G
Bindweed, field	P	------	P	P	P	N	------	P	N	P	------
Buckwheat	F	------	F	------	F	N	P	P	N	------	------
Clover, sweet	P	------	P	------	G	N	P	P	N	------	------
Cocklebur	P	------	P	------	F	N	F	F-G	N	------	------
Crabgrass	G	G	G	G	F	G	F	G	G	G	G
Dodder	P	P	P	P-F-G	P	N	------	------	N	P-F	------
Foxtail	G	G	G	G	F	G*	G	G	G	G	G
Knapweed, Russian	P	------	P	------	P	N	------	------	N	------	------
Knotweed	G	------	G	G	G	N	------	------	N	G	------
Kochia	F-P	F	G-F	G-F	G	N	G	G	N	F-G	F
Lambsquarter	G	F	G-F	G-F	G	N	F	G	N	F-G	F
Mallow	P	F	P	F	G	N	------	------	N	P	------
Mustard	P	------	P	------	G	N	G	G	N	P	------
Nightshade, cutleaf	P-G	F-G	P	P-F	P	N	N	Nf	N	F-G	G
Nightshade, hairy	P-G	F	P	F-P	F	N	F-G	G	N	F-G	G
Nutsedge, yellow	F	F-G	P	P	P	N	G	F	N	P	F-G
Oat, volunteer	G-F	------	G	------	G-F	G	G-F	G	G	------	F-G
Oat, wild	G-F	P-F	F	F-P	F-G	G	F	G	G	F-G	------
Pigweed	G-F	G	G	G-F	G	N	G	G	N	G	G
Purslane	G	G	G	G	G	N	------	F	N	G	G
Quackgrass	F-G	P-F	P	------	F-P	F	N	G	G	P	

Weeds (continued) page 2	EPTC (Eptam)	metolachlor (Dual)	trifluralin (Treflan)	pendimethalin (Prowl)	metribuzin (Sencor)	sethoxydim (Poast)	rimsulfuron (Matrix) Preemergence	rimsulfuron (Matrix) Postemergence	Clethodim (Select)	To be registered Sonalan	To be registered Outlook
Sandbur	G	G	G	------	P	G	------	------	G	G	G
Smartweed	P	P	F-P	F	F	N	------	F	N	F-G	------
Sowthistle	F	------	P	P	G	N	------	------	N	P	------
Sunflower	P	P	P	P	F	N	G	F-G	N	P	P
Thistle, Canada	P	P	P	P	F	N	------	F	N	P	------
Thistle, Russian	P	P	G-F	G	G	N	P	P	N	F-G	P
Wheat, volunteer	G-F	------	F	------	P	G	G	G	G	------	------
Comments	rate and timing very critical										

Alaska Potato Production Weed Control Efficacy Table

Weeds	EPTC (Eptam)	paraquat (Gramoxone Extra)	metribuzin (Sencor)	fluazifop-p-butyl (Fusilade)	sethoxydim (Poast)
Chickweed	**G**	**G**	**G**		
Corn spurry	**?**	**F-G**	**G**		
Fireweed	**F**	**F-G**	**F-P**		
Hempnettle	**P**	**P-F**	**P-F**		
Lambsquarters	**G**	**F-G**	**G**		
Pineapple-weed	**?**	**F-G**	**G**		
Prostrate knotweed	**?**	**P**	**?**		
Quackgrass	**G**	**P**	**P**	**G**	**G**
Volunteer Grain	**G**	**F-G**	**G**		
Wild Buckwheat	**P**	**F-G**	**G**		

E = Excellent, G = Good, F = Fair, and P = Poor.

* There may be some differences between yellow and green foxtail.

Efficacy Tables for Pest Management Tools

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

Herbicides Registered on										
MANAGEMENT TOOL	**VG**	**BLW**	**G**							
Paraquat (Gramoxone Extra)	X									
Glyphosate	X	X	X							
Metribuzin (Sencor, Lexone)		X								
EPTC (Eptam)		X								
Pendimethalin (Prowl)		X								
Metolachlor (Dual)		X								
Rimsulfuron (Matrix)		X								
Sethoxydim (Poast)		X								
IPM and Cultural Control										
Cultivate for weed control										
Scouting										
Adjust herbicide rate based on weed pressure										
Rotate herbicide classes to avoid resistance										
Choose rotational crops that compete with weeds										

VG= volunteer grain, BLW= broadleaf weeds, G= grasses

Efficacy rating symbols: E=Excellent (90-100% control), G=Good (80-90% control), F=Fair (70-80% control), P=Poor (<70% control), ?=no data but suspected

(s) = secondary pest outbreaks

(c) = tank mix

(r) = regionality differences

(rs) = resistance

Efficacy Tables for Pest Management Tools

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

Fungicides Registered on Potatoes

DISEASES																						
	In the Field																In Storage					
MANAGEMENT TOOL	**SF**	**FSPD**	**EB**	**LB**	**ED**	**SS**	**BSR**	**FUS**	**BOT**	**PS**	**PM**	**SBCS**	**BL**	**RR**	**WM**	**BS**	**PR**	**PL**	**LB**	**FDR**	**EB**	**Comments**
1, 3 dichloropropene					G																	
Azoxystrobin (Quadris)			EB	F												X						
Captan (Captan)		P		P		F																
Chlorothalonil (Bravo, Echo, Equus, Terranil)			G	G					X-?		P-(Bravo S only)											Ridomil Gold Bravo (+mefenoxam); Bravo S (+sulfur)
Copper (many products)			P	P		F																ManKocide - Griffin (+mancozeb), ridomil Gold Copper (+mefenoxam)
Copper salts of fatty and rosen acids (Tenn-Cop)			P	P																		
Cymoxanil (Curzate)				G																		Evolve - Gustafson (+mancozeb, thiophanaate-methyl)
Dazomet (Basamid)	X																					
Dicloran (Botran, DCNA)															X							
Dimethomorph (Acrobat)				G																		Acrobat
Fentin hydroxide (Du Ter)				F																		
Fluazinam (Omega)				G						P					G							
Fludioxonil (Maxim)						G-IF SEED BORNE										G				N		Maxim MZ (+mancozeb) if seed borne
Flutolanil (Moncoat)						G		G								G						Moncoat is a mixture of flutalonil and mancozeb
Hydrogen peroxide (OxiDate)				N		N																OxiDate also contains peroxyacetic acid
Iprodione (Rovral)			P												F							

Fungicides Registered on Potatoes - page 2

DISEASES																					
	In the Field															In Storage					
MANAGEMENT TOOL	SF	FSPD	EB	LB	ED	SS	BSR	FUS	BOT		PM	SBCS	BL	RR	WM	BS	PR	PL	LB	FDR	EB	Comments
Mancozeb (Manzate, Dithane, Mankocide, Penncozeb)		G	G	G		N				P		P-N										Acrobat MZ (+dimethomorph), ManKocide (+copper hydroxide), Maxim MZ (+fludioxonil), Ridomil Gold MZ (+mefenoxam), tops MZ (+Thiophanaate methyl), Tops MZ Gaucho (+thiophanate methyl, imidacloprid), Tops MZ CZ (+thiophanate-methyl& cymoxanil)
Maneb (Maneb, Manex)			G	G																		
Mefanoxam (Ridomil Gold, Ultra Flourish)																	G	G				Ridomil gold MZ (+Mancozeb), Ridomil Gold Bravo/Flouronil (+chlorothalonil), Ridomil Gold Copper (+copper hydroxide), Platinum Ridomil Gold
Metalaxyl (Ridomil)																	G	G		N		
Metam potassium (K-Pam)					G																	fungal diseases
Metam sodium (Vapam)					G																	
Metiram (Polyram)			G	G																		
Neem oil (Trilogy)																						fungal diseases
PCNB (pentachloro-nitrobenzene) (Blocker, PCNB 2E)												F			F	G						
Peroxyacetic acid (Oxidate)				N																		Oxidate also contains hydrogen peroxide
Phosphites, mono- and dibasic sodium, potassium, and ammonium (Phostrol)																	G	G	G			
Propamocarb hydrochloride (Previcur Flex)			N	G																		Previcur
Streptomycin sulfate (Agri-Mycin)							X						X									Don't know
Sulfur (many products)				P							G											
Thiabendazole (Mertect, TBZ)																N				N		Resistance

Fungicides Registered on Potatoes - page 3

MANAGEMENT TOOL	DISEASES																					
	In the Field															In Storage						
	SF	FSPD	EB	LB	ED	SS	BSR	FUS	BOT	PS	PM	SBCS	BL	RR	WM	BS	PR	PL	LB	FDR	EB	Comments
Thiophanate-methyl (Topsin M, Tops MZ)		G		G																		Evolve (+mancozeb, cymoxanil), Tops MZ (+mancozeb), Tops MZ Gaucho (+mancozeb, imidacloprid)
Trifloxystrobin (Flint)			F	G																		
Trimethylammonium chloride														G								
Triphenyltin hydroxide (Super Tin)			G	G																		
Zoximide (Gavel)			G	E																		
Section 24c Products (WA)																						
Dicloran (Botran 5F)															F							
Flutolanil (Moncut)																G						
PCNB (Blocker)															F	G						
Section 18 Products (WA)																						
Chlorine dioxide (Purogene, Anthium 200) (WA and ID)				P		P																
Biologicals and Others																						
Bacillus subtilis strain QST 713			X	X																		Don't know - very little public data
Candida oleophila isolate I-182 (Aspire)																						Post harvest fungal disease suppression Don't know - very little public
Jojoba oil (E-rase Agriculture)											X											Don't know - very little public data
Pseudomonas cepacia type Wisconsin (Deny)																						Don't know - very little public data
Pseudomonas fluorescens A506 (Blightban)																						Don't know - very little public data
Pseudomonas syringae Strain ESC-11 (Bio-save)						X		X-Post-harvest														Don't know - very little public data
Trichoderma harzianum Rifai strain KRL-AG2 (T-22, Rootshield)								X								X		X				Don't know - very little public data

Fungicides Registered on Potatoes - page 4

DISEASES																						
	In the Field																In Storage					
MANAGEMENT TOOL	**SF**	**FSPD**	**EB**	**LB**	**ED**	**SS**	**BSR**	**FUS**	**BOT**	**PS**	**PM**	**SBCS**	**BL**	**RR**	**WM**	**BS**	**PR**	**PL**	**LB**	**FDR**	**EB**	**Comments**
Pipeline Materials and possible biologicals																						
BAS 510									X						G							"pending"
BAS 516			X						X						X							"pending"
Cyazofamid (IKF-916, BAS 545F)				X																		"potential"
Ethaboxam (Guardian)				X																		"potential"
Famoxadone (Famoxate, Charisma)			X																			"pending"
Fenamidone (Reason)			X	X																		"potential"
Iprovalicarb (Melody)				X																		"potential"
Kresoxim-methyl (Sovran, Cygnus)											X											"pending"
Potassium bicarbinate (Kaligreen, Armicarb)											F											"potential" - Fair in storage for silver scurf
Pyraclostrobin (BAS-500F, Headline, Cabrio)			G	G																		broad spectrum, "pending"
Pyrimethanil (Scala)			G						X													"potential"
Biological																						
Ampelomyces quisqualis isolate M-10 (AQ 10)											X											"pending" Don't know - very little public data
Fusarium oxysporum strains								X														not listed by IR-4 Don't know - very little public data
Streptomyces lydicus WYEC 108																						soil borne fungi "pending"
Trichoderma harzianum																						various pathogens not listed by IR-4 Don't know - very little public data
Ulocadium atrum									X													not listed by IR-4 Don't know - very little public data
Vericillium lecanii											X											not listed by IR-4 Don't know - very little public data

Fungicides Registered on Potatoes - page 5

DISEASES

	In the Field																In Storage					
MANAGEMENT TOOL	**SF**	**FSPD**	**EB**	**LB**	**ED**	**SS**	**BSR**	**FUS**	**BOT**	**PS**	**PM**	**SBCS**	**BL**	**RR**	**WM**	**BS**	**PR**	**PL**	**LB**	**FDR**	**EB**	**Comments**
IPM and Cultural Control																						
Destroying cull potatoes				Y																		Good for viruses (PLRV, PVY, PVA)
Plant certified seed		Y		Y									Y	Y		Y						
Scouting			Y	Y	Y		Y		Y		Y				Y		Y	Y	Y	Y	Y	
Sort/remove decayed tubers coming into storage																	Y	Y	Y			
Sanitation		Y	Y	Y		Y							Y	Y								
Adjust fertility / irrigation practices		Y	Y	Y	Y		Y		Y		Y	Y	Y		Y		Y	Y	Y		Y	
Control weeds that are alternate hosts of diseases				Y	Y										Y							Good for viruses
Proper rotation		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y						
Spacing											Y				Y							

SF=Soil Fumigant, FSPC= *Fusarium* Seed piece decay, EB= Early blight, LB= Late blight, ED= Early dying, PLRV= Potato leaf roll virus, SS=Silver Scurf, BSR= Bacterial Stem Rot, FUS=Fusarium, BOT=Botrytis, PS= Powdery scab, PM=Powdery Mildew, SBCS=Seed Borne Common Scab, BL=Blackleg, RR=Ring rot WM=White Mold, BS= Black Scurf (*Rhizoctonia* Stem Canker) PR= Pink rot, PL= Pythium leak, FDR= *Fusarium* dry rot, SS= Silver scurf, BSR= Bacterial soft rot

Efficacy rating symbols: E=Excellent (90-100% control), G=Good (80-90% control), F=Fair (70-80% control), P=Poor (<70% control), N=None (No control), ?=no data but suspected of being efficacious.

Y = yes N = no

Efficacy Tables for Pest Management Tools

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

Nematicides Registered on Potatoes

MANAGEMENT TOOL	RKN	RLN	SRN					Comments
1,3 dichloropropene (Telone-II)	X	X	X					
Aldicarb (Temik)	X	X	X					
Chloropicrin (Telone C-17, Telone C-35)	X	X	X					Telone C-17 and Telone C-35 are mixtures with 1,3-dichloropropene.
Ethoprop (Mocap)	X	X	X					
Metam sodium (Vapam, Metam, Busan)	X	X	X					
Biologicals and others								
Myrothecium verrucaria strain AARC-0255 (DiTera WDG)	X	X	X					
Pipeline Materials and possible biologicals	X	X	X					
DMDP								"potential"
Fosthiazate	X	X	X					"pending"
Biologicals								
Hirsutella rhossiliensis	X	X	X					not listed by IR-4
Rhizobium etli G12	X							and cyst nematodes not listed by IR-4

Nematicides Registered on Potatoes - page 2

MANAGEMENT TOOL (Continued)	RKN	RLN	SRN					Comments
Non-Chemical Controls								
Use certified seed	X	X	X					
Avoid contaminated water for irrigation	X	X	X					
Avoid nondecomposed manure	X	X	X					
Fallowing	X	X	X					
Early harvest	X	X	X					
Organic manure	X	X	X					
Catch crops (oil radish and rapeseed green maure crops)	X	X	X					

RKN= Root-knot nematode, RLN= Root lesion nematode, SRN= Stubby root nematode.

Efficacy rating symbols: E=Excellent (90-100% control), G=Good (80-90% control), F-Fair (70-80% control), P=Poor (<70% control), ?=not data but suspected of being efficacious.

Y = yes   N = no

Toxicity Ratings on Beneficials in PNW Potatoes:

BENEFICIALS	BEB	DB	LW	LB	MPB	PM	PN	PW	S	SF	TF	TSS	COMMENTS
1,3 dichloropropene (Telone II, Telone C-17, Telone C-35)							P						
Abamectin (Agrimek)													
Aldicarb (Temik)	P	P			F-P				E				
Azinphos-methyl (Guthion)													
Carbaryl (Sevin)													
Carbofuran (Furadan)	F-P	F-P			F-P				G				
Chloropicrin (Telone C-17, Telone C-35)							P						
Cryolite (Kryocide, Prokil)													
Cyfluthrin (Baythroid, Leverage)	F?	F?			P?				P?				
Diazinon (WA-24c)													
Dimethoate (Cygon)													
Disulfoton (Di-Syston)	F	G-F			F-P				G				
Endosulfan (Thiodan, Phaser)	F-P	E-G			E				P				
Esfenvalerate (Asana)	F?	F?			P?				P?				
Ethoprop (Mocap)							P?						
Imidicloprid (Admire, Provado, Genesis, Gaucho)	F	F			E				E				
Malathion (Cythion)													
Malathion + methoxychlor (Malathion Methoxychlor Spray)													
Metam potassium (K-Pam)							P						
Metam sodium (Vapam)							P						

Toxicity Ratings on Beneficials in PNW Potatoes: - page 2

BENEFICIALS	BEB	DB	LW	LB	MPB	PM	PN	PW	S	SF	TF	TSS	COMMENTS
Methamidophos (Monitor)	G-P	P			E				F				ND
Methomyl (Lannate)	F	P			P				F				ND
Methoxychlor													ND
Methyl parathion (Declare, Penncap-M)	P	P	P	P	P	P	P	P	P	P	P	P	
Oxamyl (Vydate)	G?	G?	G?	G?	G?	G?	G?	G?	G?	G?	G?	G?	ND - application dependent, possibly G
Permethrin (Pounce, Ambush)	F	F			P				P				
Phorate (Thimet)	F	G-F			G-F				F				
Phosmet (Imidan)													ND - possibly soft G-E
Propargite (Comite, Omite)						P							ND
Sulfur (Micro Sulf)													ND
Alternative Insecticides													
Imidacloprid (Admire)	F	F			E				E				
Spinosad (Success)	G?	G?			G?				G?				
Thiamethoxam (Platinum, Actara)(WA-24c)	F	F			E				E				
Pymetrozine (Fulfil)	E	G-E			E				E				
Biological Insecticides													
Azadirachtin (Agroneem, Ecozin, Neemix)													ND

Toxicity Ratings on Beneficials in PNW Potatoes: - page 3

BENEFICIALS	BEB	DB	LW	LB	MPB	PM	PN	PW	S	SF	TF	TSS	COMMENTS
Bacillus thuringiensis spp. *aizawai* (Agree, Ketch, Mattch, XenTari)	E	E			E				E				
Bacillus thuringiensis spp. Berliner (BT 320 Sulfur 25 Dust)													
Bacillus thuringiensis spp. k*urstaki* (Biobit, Condor, Raven, Deliver, Javelin, DiPel, Mattch, MVP, Prolong)	E	E			E				E				
Bacillus thuringiensis strain EG7841(both *aizawai* and *kurstaki* toxins)(Crymax)													
Beauvaria bassiana (Mycotrol)													ND
Cryolite (Na aluminofluoride) (Kryocide)													SEE ABOVE
Jojoba oil (Erase ECO)													ND
Neem oil (Trilogy)													ND
Potassium salts of fatty acids (M-Pede)													ND
IPM and Cultural Control													
Transgenic varieties	F-P	E	E	E	E	E	E	E	E	E	E	E	
Resistant varieties	E	E	E	E	E	E	E	E	E	E	E	E	
Use certified seed													NA
Growers physically examine leaves													Theoretically E
Scout fields													Theoretically E
Use of economic thresholds													Theoretically E
Rotate to non-host crops 3 out of 4 years (OR)													Theoretically E

Toxicity Ratings on Beneficials in PNW Potatoes: - page 4

BENEFICIALS	BEB	DB	LW	LB	MPB	PM	PN	PW	S	SF	TF	TSS	COMMENTS
Pipeline materials and possible biologicals													ND
Bifenazate (Acrimite)													ND
Deltamethrin (Decis)													ND
Etoxozole (Baroque, Zoom)													ND
Fipronil (Regent)													ND
IKI 220													ND
Lufenuron (Match)													ND
Novaluron (Rimon)													ND
Tebupirimphos (combined with cyfluthrin) (Aztec)													ND
Tefluthrin (Force)													ND
Thiacloprid (Calypso, Alanto)													ND
Biological													
Bacillus Sphaericus (Valent)													ND
Metarhizium anisopliae (Taerain)													ND

BEB=Bigeyed bugs, **DB**=Damsel bug, **LW**=Lacewings (*Chrysopa* spp.), **LB**=Lady beetles (*Hippodamia convergens*), **MPB**=Minute pirate bugs (*Orius* spp.), **PM**=Predatory mites (*Acari: Phytoseiidae*), **PN**=Predatory nematodes, **PW**=Parasitic wasps (Ichneumonidae, Braconidae, Chalcidae families), **S**=spiders (Erigone aletris, E. blaesa, and E. dentosa (Arachnida: Araneae)), **SF**= Syrphid flies, **TF**=Tachinid flies, and **TSS**=Two-spotted stinkbug

E = Excellent survivability, G = Good survivability, F = Fair survivability and P = Poor survivability
ND = No Data