Pest Management Strategic Plan
for
Organic Potato Production in the West

Summary of workshops held on
February 16, 2006
Buhl, Idaho
and
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Portland, Oregon

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Table of Contents

Work Group

A work group consisting of organic growers, commodity group representatives, agronomists, regulators, university and USDA specialists, and other technical experts in Idaho, Oregon, and Washington met on February 16, 2006 in Buhl, Idaho. Not all aspects of the Pest Management Strategic Plan (PMSP) were covered during the meeting. The group decided to reconvene on January 9, 2008, in Portland, Oregon, to finish the PMSP and to add work group members from California and Colorado in order to represent all of the major organic potato producing states in the West.

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Summary of the Most Critical Needs in Organic Potato Production in the West

Research Needs

1. Research the impact of long-term organic soil management on pests and soil health and how that management helps plants resist pests.
2. Research organic sprout control in storage, and discover potato varieties that have longer dormancy to further prevent sprouting in storage.
3. Scientifically evaluate all biological control agents.
4. Determine how best to conserve natural enemies in an organic potato cropping system.
5. Dedicate long-term organic research sites.

Regulatory Needs

1. Add organic as a priority area for the IR-4 Project in order to cut costs for new organic pesticides.
2. Allow fast-track EPA approval for low-risk organic pest management materials as part of the Pesticide Registration Improvement Act. Determine how to work with smaller companies to help them with this process.
3. Clarify and integrate the requirements of the Good Agricultural Practices (GAP) program and the National Organic Program (NOP) so that they are not in conflict with each other. For example, manure use is restricted by GAP but allowable under NOP rules.
4. Approve new potato varieties, already in use in Europe, that have resistance to important pests (e.g., potato cyst nematode, late blight).
5. Integrate regulations and reduce barriers to producing organic potato seed in regulated seed-producing areas.

Education Needs

1. Provide a clearinghouse to disseminate organic potato pest management information in a comprehensive fashion (e.g., eOrganics). Include cultural practices and their efficacy, as well as resistant varieties. Make sure this information is available in Web-based and non-Web-based formats.
2. Educate growers about which green manure varieties are good for managing specific pests.
3. Educate USDA about the importance of funding organic research, especially long-term organic research.
4. Educate growers about the importance of good, clean, certified seed, and provide them with strategies for understanding all of the information available about certified seed. Educate them about having a plan for clean seed (i.e., not using self-saved seeds and not buying from unknown sources.)
5. Educate FDA and USDA about the importance, validity, and safety of organic methods.
6. Educate growers about soil-building research (e.g., mulch and compost addition).

Introduction

As the potato industry gathered to revise the potato PMSP in 2006, work group members expressed an interest in adding organic potato pest management to the document. Due to the major differences between conventional and organic potato production, a separate PMSP for organic potatoes was initiated.

When the National Organic Standards Board convened to advise the USDA on developing organic regulations, they described organic agriculture as follows:

> an ecological production management system that promotes and enhances biodiversity, biological cycles, and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain, and enhance ecological harmony.

The process of developing this organic potato PMSP focused on capturing and describing a systems approach of pest management for organic potato production in the West. Successful pest management in an organic potato crop depends upon the preventive actions employed throughout the entire crop rotation. While this PMSP focuses on only one crop—potatoes—in the organic cropping system, activities prior to planting potatoes are important for pest management and soil health. This document describes the current successful practices used by organic potato growers as well as methods showing promise but needing more research. Education, research, and regulatory needs for managing pests of organic potatoes in the West are also identified and prioritized.

The pest management strategies of organic producers are best characterized as "biointensive" systems utilizing cultural, physical, mechanical, and biological methods as well as some organically-approved pesticides. These methods help prevent pest establishment or population increases. By definition, preventive tactics must be imposed before pest status can be assessed from sampling and thresholds. These strategies include crop rotation, pest avoidance, and sanitation, among others. Together, the practices described below form the foundation of pest management in organic potato production.

Rotation

Organic potato growers understand that the length of time between potato crops is extremely important for pest management and soil health. A long rotation modifies the environment to reduce the likelihood of the buildup of any one soilborne pest. Good weed control and the correct choice of rotational crops is also important, as most pests target multiple plant species. Their populations can remain high if they have an ample food supply. Most growers use long rotations, which vary from 4 or more years in California, 5 to 10 years in Colorado, and 5 to 7 years in Idaho.

Avoidance

Another major preventive practice organic potato growers employ is avoiding planting in fields with a known pest problem. If field history or sampling shows that there are high levels of nematodes, soilborne diseases, weeds, wireworms, Colorado potato beetles, or potato tuberworms, growers do not plant potatoes in that field.

Sanitation of Equipment, Seed, Water, and Personnel
In non-infested fields, growers work very hard to prevent the introduction of weeds, nematodes, and soilborne and seedborne diseases by using clean field equipment, planting clean, certified seed, avoiding the use of runoff water from other locations for irrigation, screening irrigation water for weed seeds, and ensuring proper handling by personnel. Growers also control volunteer potatoes and weeds during the growing season to reduce insect pest hosts. They destroy their potato cull piles before the growing season in order to manage insects and diseases. To manage storage diseases, sanitation in storage facilities is particularly important to growers.

Variety Selection
While growers select their varieties based primarily on market demands and specific customer needs, variety selection is another tool for managing pests in organic potatoes. Differing architecture and timing of canopy closure allow some varieties to be more competitive with weeds and possibly foliar pathogens. There are also varieties with tolerance to nematodes, diseases, and insects.

Cover Crops, Including Green Manures
Some growers plant cover crops, including green manures, to help manage nematodes and diseases. The crops are also used to manage weeds, providing competition during the rotation. In addition, they are used as trap crops for insect control, and their residue is used as a mulch at the base of the potato plant to decrease the egg-laying activity of flea beetles. Some of these crops can exacerbate pest problems such as seedcorn maggot.

Crop Residue Management
Organic potato growers manage the residue of their potato and rotation crops by chopping, disking, harrowing, and incorporating residues into the soil to eliminate hosts for overwintering insects. Some growers also manage potato vines to control potato size, burn vines to reduce pathogens surviving in the residue, or destroy vines for good skin set. They also remove and eliminate volunteer potatoes in the rotational crops in order to eliminate the potato host for numerous nematodes, insects, and diseases. While growers manage crop residue for pest management, the primary reason is to accelerate plant degradation as part of their nutrient management program.

Weed host control
Weeds that host viruses, diseases, insects, and nematodes are controlled to help with pest management.

Irrigation Management
Growers manage their irrigation to help control some nematodes, diseases, insects, and weeds. Some growers use a fallow period in conjunction with irrigation for control of nematodes. For disease management, growers carefully manage their irrigation to reduce the risk of late blight and potentially to reduce some losses due to early die, late blight, white mold, and scab. In addition, the period of leaf wetting is carefully monitored to reduce foliar diseases. Proper irrigation before harvest and storage is also important in reducing the risk of disease and in managing quality (i.e., reducing bruising). For weed

management, growers withhold water soon after cultivation to kill small weeds, and then they water to promote weed flushes. Drip irrigation has the potential to further help with weed management, but most growers do not use this method. For wireworm management some growers fallow their field and withhold irrigation. Some growers apply overhead irrigation to wash insects off leaves.

Nutrition Management

Supplying nutrients to an organically grown crop is one of the biggest challenges organic growers face. This is due to high costs and minimal choices in terms of fertilizer materials. Growers manage nutrients over a cycle of three or more years. Incorporation of a legume (such as alfalfa) into the cropping system benefits potatoes by supplying a high amount of nitrogen. It also provides other rotational benefits such as weed control. Growers monitor long- and short-term nutrient trends by means of soil analysis and in-season petiole tissue analysis. Careful nutrient management helps growers manage insects and reduce disease risks and weeds. Growers avoid nutrient levels that are too high or low in order to avoid exacerbating late blight. For weed management, growers make broadcast fertilizer applications in the previous season with materials such as compost or cow manure to avoid nutrient spikes in the current season that may trigger weed germination. However, there are food safety concerns with the use of manures. In addition, some growers direct their fertilizer applications in bands (also known as side-dressing) to the potato root zone. Rapid canopy closure through adequate nutrition and other best management practices is a very effective tool in reducing weed pressure.

Harvest and Storage Methods

Growers modify their harvest date to reduce damage from insects, some diseases, and nematodes. They often select an earlier harvest date in fields with flea beetles, potato tuberworm, nematodes, or silver scurf. To manage other diseases, growers plan harvest dates to minimize disease issues. Growers harvest, heal, and store potatoes under conditions that maximize tuber healing and minimize tuber damage and disease spread. They check for proper soil or pulp temperature to manage for diseases and quality (e.g., reduced bruising). They choose not to store potatoes from fields with potato leafroll virus or high levels of pink rot, Pythium leak, or late blight. Growers on small acreages avoid in-field storage if there is a particular pest management issue, particularly silver scurf.

Beneficial Habitat

Growers take into consideration the habitat in and around their fields in order to support and encourage natural predators and parasites. Some growers plant insectaries, and most avoid broad-spectrum organic insecticides in order to conserve and support beneficial insects. Organic potato growers build soils to increase populations of beneficial soil organisms for insect and disease management. A potential method of weed management, though it is not currently practiced by organic potato growers in the West, is the use of beetle banks to support weed predation by carabid beetles. There are numerous species of carabid beetles, most of which are predatory. Some feed on organic matter on the soil surface, and some consume weed seeds. None are known to feed on potato plants.

Sampling and Scouting
Growers sample and scout for nematodes, wireworms, flea beetles (West of the Cascade Mountains region), weeds, and diseases (Verticillium wilt). They are more likely to sample if the land has been recently transitioned to organic production. Once a field has been under organic management for a number of years, growers use field history to determine how much sampling is necessary. Soil sampling for nutrients is routinely conducted.

Compost
Organic potato growers regularly apply compost as a nutrient source, but they also apply it for disease management. However, while this is a common practice, they would like research to be conducted to determine if there are benefits. High quality compost is also important in weed management, since it is not a source of weed seeds. In addition, in a study conducted at Hermiston, Oregon, relatively high rates of compost (24 tons per acre) reduced wireworm damage in potatoes (George H. Clough, personal communication). And raw manure can help control the population of nematodes. Research is needed to see if compost also helps with nematode management.

Compost Tea
A few organic potato growers apply compost tea for disease suppression. Compost tea is thought to alter the microbial composition of the leaf surface, possibly impacting diseases. However, the teas are not well characterized, and more research is needed. In addition, variability of the product causes inconsistent results. Growers are also concerned about food safety and regulatory issues.

Biological Control
There are biological products in the marketplace to treat for insects, diseases, nematodes, and weeds. Some have been shown to be effective, while others require more research. Generally, biological control products work much more slowly. Scouting and treatment timing are therefore more critical in an organic production system.

Some organic potato growers release biocontrol agents such as lady beetles and lacewings for insect control. They also release beneficial nematodes to manage cutworms, flea beetle larvae, and Colorado potato beetle larvae. The fungus *Beauvaria* is also used to manage insects.

National Organic Program
The requirements of certified organic production are described by USDA's National Organic Program (NOP). Every certified organic farm must file an organic farm plan with their certifying agency. In this plan, organic farmers outline their soil-building actions and pest management practices. The first choices for pest management in an organically-grown crop must be preventive, cultural, and physical methods, along with the introduction of beneficial insects and other organisms. If those methods are not effective, a botanical, biological, or synthetic substance on the NOP National List of Allowed and Prohibited Substances may be used. The Organic Foods Production Act of 1990 requires the Secretary of Agriculture to establish a National List of Allowed and Prohibited Substances, which identifies the synthetic substances that may be used and the

non-synthetic substances that cannot be used in organic production and handling operations. The conditions that necessitate use of botanical, biological, or synthetic substances must be documented in the organic farm plan. These inputs are only to be used as a last resort. Information on the NOP standards and guidelines can be obtained at http://www.ams.usda.gov/nop/indexIE.htm.

This document contains information on some pesticides that are available to organic farmers. Many products have not been extensively tested, summarized, or made widely available. Appendix 1 contains an explanation of rules governing the use of organic pesticide materials. Regulations promulgated through USDA's NOP program, USEPA, and state departments of agriculture are also described in Appendix 1.

Organic Potato Pest Management Strategic Plan (PMSP) Work Group

In a proactive effort to identify organic potato pest management priorities and lay a foundation for future strategies, organic potato growers, industry representatives, agronomists, members of federal agencies (e.g., USDA-Agricultural Research Service), nonprofit organizations, and university specialists from Idaho, Oregon, and Washington formed a work group. They met on February 16, 2006, in Buhl, Idaho, where they discussed organic potato production and identified critical needs. Time was not adequate to address all aspects of the PMSP, so the work group decided to reconvene. Work group members from two additional states, California and Colorado, were added to address organic potato pest management in the major organic potato producing states in the West. The work group met a second time on January 9, 2008, in Portland, Oregon, to update and complete the organic potato PMSP. The resulting document was reviewed by work group members, including additional people who were not present at the meeting. The final result is this document, a comprehensive description of pest management practices and pest-specific critical needs for the organic potato industry in California, Colorado, Idaho, Oregon, and Washington.

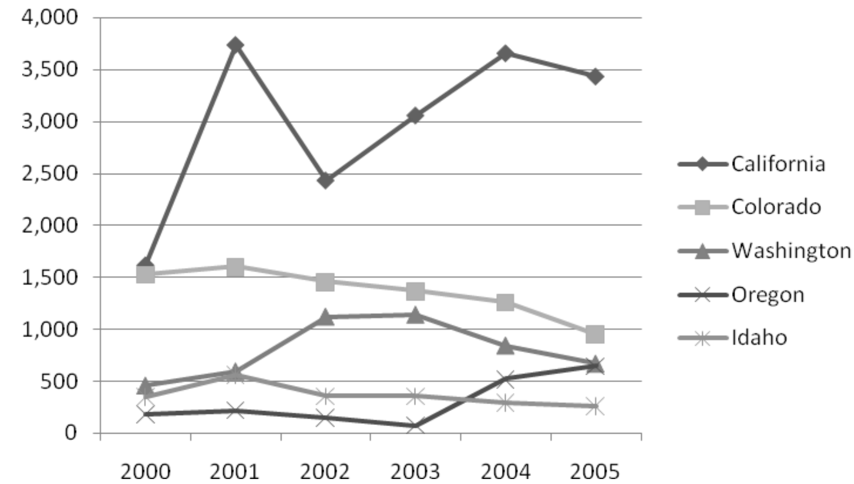
The document begins with a region-by-region overview of organic potato production in the West. The remainder of the document is an analysis of key management methods (current and potential) used in organic potato production for nematode, insect, disease, weed, and vertebrate pests. Differences among production regions are discussed where appropriate. Critical research, education, and regulatory needs are identified for each pest type. Production of potatoes grown for organic seed is not covered by this document.

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

Production Overview

Organic potato production in the West is primarily located in California (3,431 acres), Colorado (953 acres), Washington (673 acres), Oregon (645 acres), and Idaho (260 acres), according to USDA National Agricultural Statistics Service (NASS) 2005 data. Total U.S. organic potato production was 6,581 acres in 2005, of which 91% was produced in the West.

Organic Potato Acres in the West (2000–2005)
Source: USDA NASS



Organic potato production areas are grouped into the following growing regions in this document: California, Colorado, Idaho, Columbia Basin of Oregon and Washington, Klamath Basin of California and Oregon, and West of the Cascade Mountains in Oregon and Washington. Each organic potato growing region is described below.

California

In California, organic potatoes are grown in the San Joaquin Valley of Kern County, the Antelope Valley of Kern and Los Angeles Counties, and the Cuyama Valley in Santa Barbara and San Luis Obispo Counties. According to USDA NASS data, California leads the nation in organic potato production, with an average of 2,989 acres from 2000 to 2005. Roughly 300 acres of organic potatoes are grown in the Klamath Basin, which is described as a separate growing region in this document. In 2005, California organic potato acres represented 52% of total U.S. acres. The value of this production averaged $6 million from 2002–2005, although it varied widely by year. The average farm size for organic potatoes is 1,000 acres.

Organic potatoes are planted from November to March as a spring crop and in August as a fall crop, and irrigated with solid set sprinklers. The potatoes are harvested in March through July for the spring crop and in November for the fall crop. Growers plant Russet Norkotah, Cal White, Red LaSoda, and many other varieties. All organic potatoes grown in California are fresh market varieties, and most of them are shipped to the East Coast of the United States. Growers practice a 3- to 4-year rotation with various vegetables including carrots and leafy vegetables.

Colorado

In Colorado, organic potatoes are grown in the San Luis Valley in the south and Weld County in the north. From 2000 to 2005, Colorado averaged 1,362 acres of organic potatoes. In 2005, Colorado produced organic potatoes on 953 acres, making it the third largest organic potato growing region in the West, representing 14% of U.S. acres. The average yield for organic potatoes is 170 cwt per acre, which sells for an average price of $20 per cwt. Multiplying by the average of 1,000 acres of production in Colorado, this brings the value to $3.4 million. The average farm size is somewhere between 500 and 700 total acres.

Organic potatoes are planted from late March to May, irrigated, and harvested July through October. Colorado organic growers plant varieties similar to the standard varieties, including Russet Norkotah, Yukon Gold, Centennial, Rio Grande, Canela, Durango Red, All Blue, Norland, Purple Majesty, Mountain Rose, and fingerlings. Nearly all the production is for fresh market consumption. Potatoes are stored, and supplies typically last into late May to early June. Various fingerling and specialty varieties are also grown in very small quantities for seed production. Crop rotations vary, but they include barley, winter wheat, potatoes, onion, canola, alfalfa, and green manure crops. A typical rotation is winter wheat, potatoes, barley or green manure, potatoes, and 5 years of alfalfa.

Columbia Basin

In the Columbia Basin, organic potatoes are grown in Adams, Benton, Franklin, Grant, Klickitat, Walla Walla, and Yakima Counties in Washington, and Umatilla and Morrow Counties in Oregon. In 2006, organic potatoes were produced on 730 acres in the Columbia Basin region of Oregon, which represented 87% of Oregon's total organic potato acres. In 2007, organic potatoes were produced on 1,552 acres in the Columbia Basin region of Washington, which represented 83% of Washington's total organic potato acres. With approximately 2,280 acres, the Columbia Basin is the second largest organic potato producing region in the West. Organic potatoes for processing yield roughly 30–32 tons per acre, while fresh potatoes (Norkotah) yield around 22 tons per acre. Organic processing potatoes sold at $130 per ton in 2007 (plus incentives for size, grade, and quality), and fresh market potatoes (Norkotah) typically sold at $25 per hundredweight (cwt). Organic potato production in the Columbia Basin is estimated at around $19 million per year. Organic potatoes are grown on farms that vary greatly in size from 6 to 5,590 acres of organic production, with an average of 1,247 acres. The farms with large numbers of organic potato acres also grow conventional potatoes.

Organic potatoes are planted in the Columbia Basin from March through April, irrigated under center pivot systems and sprinklers, and harvested July through November. Alturas, Ranger Russet, Shepody, Umatilla Russet, and Russet Burbank are grown for processing. Process varieties are grown on contract. Norkotah is the primary variety grown for the fresh market. Yukon Golds are also grown. A typical rotation is green peas, sweet corn, potatoes, sweet corn, onions or vegetable seed or grains, then alfalfa.

Idaho

In Idaho, organic potato production is located primarily in the Magic Valley region around Twin Falls and, more recently, in eastern Idaho near Idaho Falls. From 2000 to 2005, an average of 365 acres of organic potatoes was produced in Idaho. In 2005, Idaho ranked fifth by state for organic potato acres in the five western states and had 4% of U.S. acres. According to the Idaho State Department of Agriculture, Idaho growers produced 495 acres of organic potatoes in 2007, compared with 157 acres in 2006. Organic potato production in Idaho is valued at approximately $1.5 million, based on an estimated production of 290 cwt per acre for 500 acres.

Organic potatoes are planted in April, grown under sprinkler irrigation, and harvested in September and October. Russet Norkotah (russet skin), yellow-skinned, and red-skinned varieties are grown for the fresh market, and Ranger Russet, Russet Burbank, and Defender are grown for processing. Farmers grow 20 to 160 acres of organic potatoes in a given year and rotate with organic alfalfa, grains, onion, and beans in a 4- to 7-year rotation.

Klamath Basin

The Klamath Basin encompasses the northern portions of Modoc and Siskiyou Counties in California and the southern portion of Klamath County in Oregon. From 2000 to 2003, organic potatoes comprised a relatively small segment of the Basin's potato acreage. However, this acreage has steadily increased annually. In 2007, Klamath Basin growers produced approximately 186,875 cwt of potatoes on 575 acres. Approximately half of the acreage is produced on high-organic-matter soils in the Tulelake area, with the remainder planted on mineral soils in Klamath County. Organic potato production in the Klamath Basin is valued at $1.96 million, based on an estimated production of 325 cwt per acre for 575 acres.

Organic potatoes are planted early April through late May, grown under solid-set sprinkler irrigation, and harvested mid-August through mid-October. Approximately half of the organic acreage is planted with russet varieties, with Russet Norkotah and GemStar Russet being the most commonly planted varieties. Remaining acreage is comprised of various red, yellow, and white-skinned varieties, fingerlings, and other specialty-types. Currently, 99% of the organic acreage is produced for the fresh market, with a very small segment used for processing into chips. It is anticipated that processed acreage for organic chips could increase significantly in the future. Cropping rotations in the Tulelake area have essentially followed ground that has been flood-fallow (flooded and not planted with a crop) for a minimum of three years prior to potato planting. Subsequent rotations include small grains, dry fallow, and potatoes prior to reverting back to flood-fallow. Rotations on the mineral soils in Klamath County include perennial grass pasture or alfalfa, small grain, and potato. Under these conditions, potatoes are rotated in a 3- to 30-year cycle.

West of the Cascade Mountains

In the West of the Cascade Mountains region, organic potatoes are grown on 320 acres in Skagit, Snohomish, and King Counties of Washington, and Douglas, Lane, and Yamhill Counties in Oregon. In 2006, organic potatoes were reported to be produced on 4 acres in the West of the Cascade Mountains region of Oregon, which represented 0.5% of Oregon's total organic potato acres. In 2007, organic potatoes were produced on 313 acres in the West of the Cascade Mountains region of Washington, which represented 17% of Washington's total organic potato acres. The lower production in Oregon is due to intense late winter and spring rains (increasing late blight potential and making early plantings very difficult to get into the ground), heavier soils (especially in the Willamette Valley), and tuber flea beetle.

Yields for red potatoes, fingerlings, and yellow potatoes are around 10–16 tons per acre. The Seattle terminal market prices for 50 pounds as of January 29, 2008, were $34.95 for red potatoes, $32 for Yukon, and $27 for Russet. Organic potato production in the West of the Cascade Mountains region is valued at approximately $5 million. Farmers in the Skagit Valley of Washington are, on average, managing 220 acres organically, while their total farm size for both conventional and organic production averages approximately 1,000 acres. In the Willamette Valley of Oregon, organic farms are typically fairly small (5–50 acres of diversified vegetables), and they typically market their potatoes directly. The Oregon growers in this region plant 0.5 to 5 acres in a year.

Organic potatoes are planted in this region April through June and harvested July through October. In Washington, around 90% of the land is irrigated. The major method is "big gun" irrigation. Some very small parcels of land are irrigated with hand-shift overhead irrigation systems. Ranger Russet, Alturas, Umatilla Russet, and Russet Burbank are grown for processing. The main varieties grown are Chieftain (Red), Yukon Gold, Cascade White, and several fingerling types, with the major one being Banana. In Skagit County, the vast majority of organic acres come from immediately-certifiable parcels of pasture land that have been in pasture for 10 to 20 years. Once potatoes are harvested, the land is "retired" back to pasture. Some organic land is in rotation with field corn and cucumbers. In this region of Oregon, organic farmers typically grow potatoes only once every four or more years.

Nematodes

Nematode infestation primarily reduces potato quality but can also reduce yields, in either case contributing to economic loss. Predominant nematode pests of organic potatoes in the West are root-knot nematodes (*Meloidogyne hapla, M. incognita* and *M. chitwoodi*), root-lesion nematodes (*Pratylenchus neglectus* and *P. penetrans*), stubby-root nematodes (*Trichodorus* and *Paratrichodorus* spp.). The potato cyst nematode (*Globodera pallida*) only occurs in Idaho and in very isolated locations. Nematodes are of concern to growers not only because of their feeding damage but also their role in some economically important potato diseases. For example, there is a relationship between the feeding of one species of root-lesion nematode (*P. penetrans*) and early dying/Verticillium wilt infection (*Verticillium dahliae*). Fortunately *P. penetrans* is not widely distributed. And while stubby-root nematodes do not cause direct damage in potatoes, they are vectors of tobacco rattle virus (TRV), which causes corky ringspot in potatoes.

Nematodes are managed by using several of the foundation practices described in the Introduction. The descriptions below are specific to nematode prevention and management.

Rotation
Many organic potato growers in the West find that their diverse rotations and years of organic management result in few nematode pest problems. Growers try to avoid rotation crops and weeds that are also hosts for potato parasitic nematodes. Crop rotation for nematode management is most important for recently-transitioned fields.

Avoidance
Growers rely upon their field histories to manage for nematodes. If there is a field history of nematode pests, growers avoid planting potatoes in that field until the populations can be lowered to acceptable levels.

Sampling
Sampling is widely practiced during the transition of new fields, in the early years of organic management on a field, and if the field history indicates there has been a nematode problem in the past.

The best time for nematode sampling is usually in the fall prior to planting potatoes, when soil conditions are favorable for nematode activity. Soil samples are taken from the plant root zone, and whole plant samples are taken from areas in the field showing poor plant growth symptoms. Growers use soil and plant sample results, along with field history, to determine nematode population levels and the risk they may pose to a potato crop.

Sanitation
Growers work very hard to prevent the introduction of nematodes to their fields by using clean field equipment, planting certified seed, avoiding the use of runoff water from other

locations for irrigation, and avoiding the introduction of nematode-infested plant material.

Weed Host Control
While growers primarily manage weeds to reduce their competition with potatoes and rotation crops, weed control (including for volunteer potatoes) is also beneficial in nematode management, because it removes potential nematode hosts.

Variety Selection
If necessary, growers choose potato varieties for particular fields based in part on nematode population levels. If the field history or soil samples indicate the presence of root-knot nematodes, for example, growers are restricted to early-harvest varieties such as Russet Norkotah or Shepody. There are also some potato varieties that show good tolerance to Tobacco Rattle Virus (TRV), which is transmitted by stubby-root nematodes. Gemstar, for instance, does not exhibit TRV symptoms. Russet varieties resistant to TRV symptoms and to Columbia root-knot nematode are also in development. Currently, work is just getting started at the University of Idaho to screen breeding lines that have reported potato cyst nematode (*Globodera pallida)* and golden cyst nematode (*G. rostochiensis)* resistance in their background. Varieties with known resistance to potato cyst nematode are all European varieties and are not commercially available to U.S. growers.

Fallow Cultivation
If there is a nematode problem, some growers cultivate fallowed land repeatedly to expose nematodes to heat and dry air. This practice reduces nematode populations in the upper 12 to 18 inches. Some growers in California irrigate during the fallow (wet fallow) to stimulate egg hatch and upward migration.

Green Manure Incorporation
Organic potato growers may use this practice during transition and during the early years of organic production. Growers also use green manures to manage disease and soil health.

Certain green manure crops release biologically active compounds when they are chopped and disked into the soil. Some of these compounds may have nematicidal activity in the soil. Some plants in the Brassicaceae family, namely oilseed radish, mustard, arugula, and rapeseed, have been found to affect nematode populations when used as green manures. They produce isothiocyanates, which act as biological fumigants when correctly incorporated into the soil. Some sudangrass-sorghum hybrids produce hydrogen cyanide and can be used as a method of biofumigation.

Growers use different species and varieties of green manures in organic potato production, including the rapeseed cultivars ‘Humus’ and ‘Dwarf Essex,’ sudangrass hybrids ‘Trudex 8’ and ‘Trudex 9,’ the sorghum-sudangrass hybrid ‘Sordan 79,’ the oilseed radish cultivar Adagio, mustards (*Sinapis alba* and *Brassica junceae*), and arugula. Use of a particular type of green manure crop depends upon its chemical composition, is often cultivar-specific, and may work short-term as a trap crop in the case of some arugula. While some growers use green manures, there is a need for more research into the specific varieties that can help manage specific nematodes. Some research has shown that beneficial nematodes may also be negatively impacted by green manure incorporation, but populations have quickly recovered.

Pesticide Product Application

In general, organic potato growers are not using pesticide product applications for nematode management. Some growers in California have used products during the transition years and in the early years of certified organic production.

Sesame plant and seed oil products

Plant oils derived from sesame seeds, such as DragonFire-CPP (Poulenger USA), are available and can be used as a drench, applied multiple times from preplant to postharvest. These products are relatively new, and research into efficacy is needed. DragonFire-CPP (formerly called Ontrol) has been used in potatoes in Colorado and in other crops in California.

The product Nemagard (Natural Organic Products Int.) is made of ground sesame plants and can be applied preplant. Growers are not currently using this product.

Azadirachtin-based products

Azadirachtin-based products are derived from the neem tree, *Azadiracta indica*. Azadirachtin acts mainly as an insect growth regulator and also has some ability as an anti-feedant and oviposition deterrent (*Resource Guide for Organic Insect and Disease Management*). University of California researchers have investigated the use of azadirachtin-containing products through drip irrigation and found favorable results. There are several Organic Materials Review Institute (OMRI)-approved products registered for potatoes that contain varying percentages of azadirachtin, and one product is premixed with sesame oil.

Not all azadirachtin-based products provide specific information on nematodes. A very limited number of organic potato growers are using azadirachtin-based products.

Mustard seed meal

While not currently used by organic potato farmers, mustard seed meal will become more available and convenient to use as biofuel production plants become more prevalent in potato production areas. Mustard seed meal is a by-product of biofuel production and has been shown to have many desirable and highly effective green manure characteristics. Before it can be used for nematode management, further research is needed to improve this use, and it must be registered by EPA as a biopesticide. There may also be NOP compliance issues related to how the meal is produced in the biofuel process.

Biological controls

Some biological controls are also available, including *Burkholderia cepacia* (bacterium) and *Bacillus chitinosporus* (bacterium). Growers are not regularly using these. A limited number of growers in California have used *B. chitinosporus* during transition and in early years of organic production.

Root-knot nematodes (*Meloidogyne* spp.) can be a concern, depending upon species, in organic potato regions in the West. Root-knot nematodes are not present in all fields. 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. Southern root-knot nematode (*M. incognita*) is found in California. Plants infected with *Meloidogyne* spp. develop knots or galls of varying sizes and shapes on their roots. Typical symptoms include stunting, yellow foliage, wilting in the presence of adequate soil moisture, or general nutrient deficiencies. Severely infected plants also suffer from secondary pathogens that cause roots to rot in the field. Infestation can render tubers unmarketable. When the level of infected tubers reaches 6–10%, processors generally reject all potatoes from that field. Packers can sort and remove infected tubers, depending on infection levels and time of year. These nematodes have a wide host range that includes wheat and alfalfa, leading to population increases when potatoes or other susceptible crops are grown in rotation with potatoes.

Growers' primary methods of management include avoidance, long rotations, and sanitation. If this nematode is present, growers often avoid planting potatoes. Some mustard green manures have been shown to reduce root-knot nematode levels.

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

Growers' primary method of management is long rotations to avoid buildup of root-lesion nematodes and *V. dahliae*.

Stubby-root nematode (*Trichodorus* and *Paratrichodorus* spp.) feeding injury is not economically important and is rarely visible. Stubby-root nematodes are economically important pests because they vector Tobacco Rattle Virus (TRV). Corky ringspot disease is a symptom of TRV. When the level of infected tubers reaches 6–10% or higher, processors generally reject all potatoes from that field. This threshold does not apply in the case of direct marketing, although USDA standards need to be considered. Growers in Washington State are having more problems with stubby-root nematodes in recent years. Corky ringspot is common in the mineral soils of the Klamath Basin.

When trying to control stubby-root nematodes, it is important to understand their mobility in the soil and that they have a very extensive host range. 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.

Potato cyst nematode (PCN) (*Globodera pallida*) was discovered in the United States for the first time in a few fields on April 19, 2006. Potatoes, tomatoes, and eggplants are the principal crops of economic importance attacked by PCN. Damaging populations of the nematode develop when potatoes follow potatoes. Other plants in the Solanaceae family, such as nightshade, could also be hosts for PCN. PCN is a soilborne organism and rarely infects potato tubers or seed. Consequently, the primary means of spread of PCN are by cysts being transported in soil on farming equipment, by infested soil adhering to seed potatoes, in tare dirt, and by air (in windy areas). Spreading of PCN via seed would only occur if infested soil adhered to the seed tubers. Increased nematode populations increase the risk of spread.

Once a farm is known to have PCN contamination, every precaution must be taken to prevent soil movement from the infested land. Growers with fields where PCN has been found are not able to produce organic potatoes, because currently all fields found with PCN are placed under quarantine and into a government-financed eradication program. Infested fields are fumigated with methyl bromide and tarped early in the spring. A biofumigant is planted and later worked into the soil. In the fall the field is treated with Telone fumigant, and a winter cover crop is planted. During this process extensive soil surveying is done to test the efficacy. This process is repeated every year until no more cysts are found. A bio-assay of formerly infected soil is then done in a secure greenhouse, where three potato crops are grown in succession to see if the population redevelops. Farms adjacent to PCN infested fields must follow sanitation practices to avoid the spread of PCN. Any person or any farm equipment coming in contact with infested fields must be sanitized. Types of businesses that are regulated include potato farms, potato processing and packing facilities, used farm equipment dealers, custom fertilizer applicators, and businesses such as utility companies or surveyors that perform work on infested land. Trees or sod barriers between fields and along highways help to prevent soil movement and the spread of PCN.

Critical Needs for Management of Nematodes in Organic Potatoes in the Western United States

Research

- Improve sampling techniques for nematode populations to reduce sampling error. (Sampling error is high due to spatial variation in nematode populations.) Determine if aerial imagery from a previous crop can be used to determine nematode populations within the field.
- Continue research on resistant varieties grown for organic production, and develop new varieties resistant to other nematodes.
- Develop fresh potato cultivars with resistance to nematodes. Most of the breeding research for resistant varieties is done for processing cultivars, and most organic potatoes are sold fresh.
- Research what effect building the soil biota (all of the organisms living in the soil)—through the use of cover crops, green manures, crop rotation,

and compost addition—has on the control and activity of nematodes over the short, medium, and long term.
- Document grower experience, which indicates that long-term organic management methods, including the use of compost and green manures, have significantly reduced nematode problems.
- Research the benefits and drawbacks of rotational partners (including green manures, fallow, and weed hosts) with regard to pest issues in potatoes over the short, medium, and long term. Variety-specific research needs to be done. For example, rotating some varieties of sweet corn with potatoes increases nematode populations, whereas rotating with other varieties helps reduce nematode populations.
- Research the integration of cover crops into potato production, including the effectiveness of overseeding (aerially seeding during harvest operation) cover crops before wheat crop harvest in a wheat-cover crop-potato rotation.
- Research the effect of compost teas and humic acid on soil biology for the control of nematodes.
- Research the effectiveness of sesame seed oil and other products in nematode management.
- Dedicate university or farmers' land for organic potato production research, to be managed organically for the long term.

Regulatory
- Facilitate the registration of *Brassica* meals as a biocontrol for nematodes and their approval for use in the organic system.
- Regulate and enforce strict seed certification and phytosanitary standards across state and national borders to prevent the introduction of new pests.
- Address state rules on seed potato production areas so that growing organic potato seed is allowed as long as it does not jeopardize conventional seed production. Organic seed may have to be grown in isolated areas away from Potato Seed Management Areas.
- Encourage USDA to provide additional funding for organic research.

Education
- Educate growers about the importance of sampling and nematode identification.
- Educate growers, consultants, and other industry personnel about the findings of future research on the benefits and drawbacks of crop rotation partners for pest issues in organic potatoes.
- Continue to educate growers about existing green manure varieties.
- Educate growers about the need to visually inspect seed for nematodes, even if the seed is certified. Certified seed is not necessarily tested for nematodes.
- Educate growers about the weed hosts of specific nematodes in order to target the control of tobacco rattle virus (TRV).

- Educate growers about the importance of sanitation in nematode management.
- Educate seed producers about organic seed production, the varieties that organic potato growers want, and the need for high-quality certified organic seed.
- Educate growers about the seed certification process, the difference between certification and shipping point inspections, and how growers should work with the process.
- Educate organic growers about organic research being done by university researchers.
- Educate growers, extension personnel, and other industry personnel about regulatory issues (e.g., NOP standards, seed certification).
- Educate extension personnel about how best to distribute information to organic potato growers.
- Provide accessible, Web-based pest management information about organic potatoes, including an online clearinghouse for research data (potentially an eXtension Web site for organic potato growers).
- Provide a regional newsletter containing pest management information for organic potato growers.
- Educate organic potato growers about the resources provided to them by PotatoNet at Oregon State University and the electronic mailing list run by Oregon Tilth. (Postings are very infrequent.)
- Develop a list of organic growers in the region for dissemination to researchers at University of California, Colorado State University, University of Idaho, Oregon State University, and Washington State University (the five universities) so they can get information out to organic growers.
- Develop a list of organic seed suppliers.
- Develop a list of heirloom potato varieties, detailing their advantages and disadvantages.
- Educate university researchers about the need for dedicated organic research land.
- Create a regional organic work group for research activities (e.g., through the Western IPM Center).
- Educate growers and agriculture professionals about how to convey organic farming issues to legislators (i.e., lobbying).

Insects

While the major insect pests of organic potatoes in the West vary by growing region, the list includes Colorado potato beetle, green peach aphid, leafhoppers, potato psyllids, potato tuberworm, seedcorn maggot, tuber flea beetle, and wireworms.

Insects are managed by using several of the foundation practices described in the Introduction. The descriptions below are specific to insect prevention and management.

Rotation
Many organic potato growers in the West find that their long rotations are a component of their insect management. Rotation partner selection is also important, as previous crop residues or volunteers may host pests. Before planting in a field that has been in grasses or sage brush steppe, growers try to determine if wireworms are present.

Avoidance
Growers rely upon their field histories to manage for insects. If there is a field history of wireworms, potato tuberworm, or Colorado potato beetle, growers avoid planting potatoes in that field.

Scouting
Organic potato growers rely on scouting as one of their major management tools for a variety of insect pests.

Sanitation
Overall sanitation measures are an important way organic potato growers manage pests. Some growers stated that sanitation is important in insect management and that they work hard to prevent the introduction of insect pests, while others said it is hard to avoid introducing insect pests. Growers are careful to not store tubers that are infested with tuberworms.

Weed Host Control
Organic potato growers primarily manage weeds in order to reduce competition with potatoes. Weed control is also beneficial in insect management, because it removes additional host plants for certain insect pests.

Variety Selection
If needed, growers choose potato varieties for particular fields based in part on insect population levels, such as potato tuberworm.

Irrigation Management
Some growers withhold irrigation and leave fields fallow to reduce wireworm levels, but weeds have to be carefully managed in this situation. Some growers also use overhead irrigation to remove insects from the leaf surface. Proper irrigation management to prevent soil cracking helps to prevent tuberworm infestation.

Nutrition Management
Soil and plant nitrogen levels are monitored to ensure optimal plant health and growth. In general, growers find a balanced nutrient program to be important in managing insect pests because it makes the crop healthier and less attractive to pests and slows insect pest population growth.

Harvest and Storage Methods
Growers harvest early if there is a flea beetle or potato tuberworm problem. In addition, growers seal cracks in the soil at vine-kill to avoid potato tuberworm damage. Organic potato farmers with small acreage avoid in-field storage of their potatoes if there is a significant insect pest problem.

Beneficial Habitat
Growers plant insectaries to support and encourage natural predators and parasitoids. These natural enemies are further conserved by reducing the use of broad-spectrum organic insecticides. Growers also consider the role of beneficial soil organisms in insect control when they implement soil-building practices.

Compost
Relatively high rates of compost (24 tons/acre) were shown to reduce wireworm damage in a study conducted on potatoes in Hermiston, Oregon. The addition of compost or organic matter makes soil conditions more favorable for the development of existing symphylans and seedcorn maggot. In particular, seedcorn maggots lay eggs heavily in soils with decomposing organic matter.

Biological Control
Some organic potato growers release biocontrol agents such as lady beetles and lacewings to manage insect pests.

The following are major insect pests of organic potatoes in the West:

Colorado Potato Beetle (CPB) is one of the most important post-emergence pests of organic potatoes grown in Idaho and the Columbia Basin, but it is not a major pest in California, Colorado, or the West of the Cascade Mountains region. There are no CPBs in the Klamath Basin. CPB has one to three generations per year, depending on the length of the growing season. CPB invades potato fields as an adult and lays 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 problem during the growing season. If larvae are not controlled, they can cause 70–100% defoliation, death of the plant, and 40% or more yield loss.

CPB can be managed preplant by extending the time between potato crops, selecting a field far from the previous year’s potato crop, and controlling potato volunteers and nightshade weed species. The farther away the new potato field is located from the previous year’s field, the better. In a study of conventional potatoes, insecticide use was reduced by 50% when the field was 330 to 980 yards away, compared to insecticide use in a non-rotated field (Weisz et al., 1994). A further study by Weisz et al. (1996) indicated a maximum CPB dispersal of approximately 1,000 yards. In addition, CPB finds it difficult to fly out of foliage that is more than a few inches high, so CPB migration can be reduced by planting a crop that will be several inches tall by the time beetles emerge. Growers control potato volunteers and weeds, such as nightshades, in surrounding areas, since overwintering CPB feeds on these before walking or flying to potato fields.

After emergence, CPB is managed in Idaho and the Columbia Basin with scouting and subsequent hand removal of CPB adults along the field margins. While not commonly used, a sweep net can be used to capture many adults. Growers also manage CPB by conserving natural enemies, including ground beetles, predatory stink bugs, lady beetles, and small hymenopteran (wasp), and dipteran (fly) parasitoids.

Flaming, bug vacuum machines, and barriers are used by growers in other parts of the country but not in the West. Growers generally do not have the heavy CPB pressure that is present in the East, so they do not resort to flaming. Bug vacuums are also more common in the East but are not used in the West. The fields are too large, and growers avoid entering fields with equipment after reservoir tillage and canopy closure. Barriers (ditches lined with plastic) can be used to stop the movement of CPB from nearby overwintering sites, but they are not feasible in Idaho where CPB flies, or in the Columbia Basin where fields are too large.

Growers also use organic insecticides. Spinosad (Entrust) is widely used but expensive. Azadirachtin (Aza-Direct), derived from the neem tree, is also widely used. Other neem-based products (Neemix, Neemazad) are used as a deterrent and insect growth regulator. While pyrethrins (PyGanic) are not widely used and are expensive, a few growers use them as a spot treatment along field edges. A few growers use garlic oil spray mix as a repellent, but research is needed to document effectiveness. Growers used to apply *Bacillus thuringiensis* (Bt) var. *san diego*, but no organically-approved Bt for use on CPB is currently available. The fungus *Beauveria bassiana* has also been shown to have some effectiveness in control of CPB, but it is used little, if at all, in western potatoes.

Flea beetles are the most important post-emergence pests on the west side of the Cascade Mountains. Flea beetles are becoming an emerging pest in the Klamath Basin. Both the tuber flea beetle and potato flea beetle are occasional pests in northern Colorado. Tuber flea beetles overwinter in the areas surrounding potato fields. Adults feed on the foliage, causing a shot-hole type of damage. In late spring, female beetles lay eggs at the base of plants. The larvae feed on roots and tubers. In severe situations, the yields from entire fields can be rendered unmarketable. The tuber flea beetle can transmit potato diseases such as spindle tuber and brown rot, and the leaf wounds may allow entry of airborne or waterborne disease organisms. Western potato flea beetles are also present in the West of the Cascade Mountains region, but they are not a major problem for organic producers.

Growers manage tuber flea beetles by planting far from sources such as winter potatoes and solanaceous weeds. Growers also carefully monitor and take control measures along their field borders. By making extra high hills at the base of potato plants, growers make oviposition more difficult for the beetles. Growers on small-acreage farms in the West of the Cascade Mountains region sometimes pile straw mulch around the base of potato plants, which interferes with egg laying. Growers occasionally use row covers, but this only works if the plants are not a source of tuber flea beetles. Row covers are not widely used, because they are difficult to use, time-intensive, and not cost effective.

Some growers use entomopathogenic nematodes for flea beetle control. Research at Oregon State University with *Steinernema carpocapsae* has shown a moderate reduction in damage from tuber flea beetle larvae.

Most organic potato growers do not use organic insecticides because of the economics, the nontarget impacts, and the perception that they are not needed. If some of the available organic insecticides, including spinosad (Entrust), pyrethrins (PyGanic), and azadirachtin (Aza-Direct), were shown to be efficacious, growers might choose to use these products. Growers in California have had a control rate of 50–75% per application with these products. A problem, though, is that tuber flea beetles continually reinvade.

Green Peach Aphid (GPA) vectors potato viruses and is one of the most important post-emergence pests of organic potatoes grown in Idaho and the Columbia Basin. GPA is also an important pest in the West of the Cascade Mountains region in Washington and the Klamath Basin because of seed potato production. 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 it is especially important because it reduces crop quality. Infected plants produce tubers with an internal discoloration defect called net necrosis. Net necrosis is most severe in long-season potato varieties, especially Russet Burbank, and it increases in severity during storage. PVY infections cause minor effects on potatoes during the year of infection, but they can be a serious problem in seed production by causing substantial losses when infected seed is subsequently planted. Potato aphid overwinters on wild roses and is located in all organic potato-growing regions of the West. While potato aphid is a vector, it causes only minor problems.

Organic potato growers' main method of managing GPA is to plant clean, certified seed. If fields are planted with potatoes that are largely free of viruses, and if there are few sources of these viruses in nearby fields, transmission of viruses by aphids can be minimized. In areas with severe PLRV spread, less susceptible varieties can be planted.

Aphids that develop in potato growing areas with cold winters spend the winter as eggs on certain specific woody plants. Green peach aphids survive between seasons on a limited number of *Prunus* species (e.g., apricot, peach, some plums). Elimination of these overwintering host plants, or treating them in spring with dormant season applications of horticultural oils, can be very effective in limiting the number of aphids that develop in a region. This approach can be most effective where plantings have some isolation and where eradication of aphids on winter host plants is practiced over a wide area, such as has long been the case in the San Luis Valley of Colorado. This approach is less successful with potato aphid, which can survive winter on many different *Rosa* species.

Growers also control secondary weed hosts (mustards, nightshades, ground cherries, and volunteer potatoes), to which aphids migrate before potato crops are available for colonization. Growers pay particular attention to hairy nightshade, which is very susceptible to PVY and can be spread to potatoes. Large numbers of aphids are present in home gardens and in bedding plants, so growers also consider avoiding these sources.

Some growers establish insectaries across the farm to encourage natural enemies that target aphids, such as hoverflies, lady beetles, lacewings, and certain parasitoid wasps. A few growers release lady beetles, lacewings, and *Beauvaria bassiana*, but research on efficacy is needed. Growers also manage their soil fertility to make the plants less attractive, although data demonstrating effects of soil nutrition on colonization of potatoes by aphids has not been fully developed.

Organic potato growers have few effective options for controlling aphids on potatoes, and they are careful to minimize adverse effects on natural enemies of aphids by pesticide applications. Furthermore, aphids tend to be hidden on lower leaves, and very thorough plant coverage is required to get control. Some growers have used the following organic products: azadirachtin (Aza-Direct), insecticidal soaps, pyrethrins (PyGanic), and certain essential oils (Ecotrol, others). These products all need further testing for aphid control in potato.

Leafhoppers are one of the most important post-emergence pests of organic potatoes grown in California and the Columbia Basin, but they are only a minor pest in Colorado, Idaho, the Klamath Basin, and the West of the Cascade Mountains region. The most important leafhopper for potato producers in the West is the beet leafhopper (*Circulifer tenellus*). Beet leafhoppers live and reproduce mostly in weeds on non-irrigated ground. The reason this leafhopper is important is that it transmits beet leafhopper-transmitted virescence agent (BLTVA) phytoplasma. Some level of BLTVA is transmitted to potatoes every year, but the virus is extremely severe in years when beet leafhopper numbers are highest.

Leafhoppers in the genus *Empoasca* occur throughout the western states. However, the species present in the western region only cause minor leaf flecking injuries, and potato growers are not managing them.

The beet leafhopper's favorite food plants include wild mustards, kochia, and Russian thistle. Controlling these favored hosts is a cultural management option. Indications are that beet leafhoppers living near a potato field may be most important in BLTVA transmission. Therefore, controlling the beet leafhopper's favorite weed hosts near potato fields may reduce BLTVA incidence. The fact that leafhoppers migrate from long distances, though, makes it more difficult for growers. Once leafhopper adults begin flying, weed mowing is avoided. Beet leafhoppers like to land on plants with bare soil around them, so reducing skips and spacing between plants can lessen beet leafhopper incidence.

Some growers apply organic insecticides, including pyrethrins (PyGanic) and azadirachtin (Aza-Direct). These growers find the insecticides provide partial control, but then more leafhoppers enter from outside fields and can transmit viruses within a few minutes after feeding. This helps explain the erratic results of insecticide use in the fight against beet leafhopper-transmitted diseases.

Potato psyllids are the major pest of organic potatoes in Colorado, a major pest in the Columbia Basin, and an occasional problem in California. They are a migratory insect that spends winters in southern California, parts of northern Mexico, and Texas, dispersing northward as temperatures become too hot. Areas that are outside the migratory routes of the insect (e.g., Idaho) are rarely, if ever, infested by this insect.

Damage is caused by the feeding of the immature nymphs, which introduces saliva that can move systemically and has very toxic effects on plant growth, producing a disorder known as "psyllid yellows." Leaf discoloration, curled leaves, and thickened internodes are common above-ground symptoms that develop from psyllid feeding. Tuber size and quality are seriously affected, and this insect has historically sometimes caused near-complete crop loss during outbreak years. Potato psyllid recently has been implicated in the potato disease "zebra chip," which has devastated chipping potatoes in many production areas in northern Mexico and southern Texas.

As potato psyllids are irregular in occurrence, growers use sweep nets to sample for the presence of adults. Conventional potatoes have a treatment threshold of two adults per 100 sweeps. Yellow pan traps can also be used to detect winged insects. Nymphs must be sampled by examining leaves, and since they are highly clumped in distribution, a large number of leaves (100+) must be examined to reliably detect psyllids if they are present.

Sulfur dust has long been used for control of potato psyllid and remains one of the most effective controls for this insect.

Natural enemies of potato psyllid primarily include various predatory bugs, such as minute pirate bugs and damsel bugs.

Different potato cultivars respond in a range of different ways to potato psyllid. Early cultivars may sometimes avoid problems caused by migrant psyllids, and some cultivars appear to be less damaged by effects of psyllid toxins. More research is needed to identify potato cultivars that are more tolerant or resistant to potato psyllid.

Potato tuberworm is a major pest in California's Central and Salinas Valleys, and in the Columbia Basin of Oregon and Washington. A limited number of adults have also been found in western Idaho and the Klamath Basin, but potato tuberworm is not currently a problem in these areas. There are a few factors that predispose a field to tuber damage by tuber moth:

a) *Dry Soil.* Research shows that dry soil due to furrow irrigation, drying under sprinkler irrigation or drought, or soil cracking that results from stopping irrigation lead to tuber damage. Conversely, wet soil prevents almost all tuber damage by sealing soil cracks and reducing their incidence.
b) *Dead Vines.* Tuberworm larvae live in the leaves and stems of potato plants during the growing season, and all evidence suggests that they prefer green

foliage over tubers. So, almost all tuber damage occurs after vines begin to die. Dry soil during this time makes tubers especially vulnerable.

c) *Exposed or Shallow Tubers.* Research around the world has shown that tubers infested by tuberworm larvae are almost always within 2 inches of the soil surface. Tubers deeper than 2 inches are rarely infested. Varieties that set tubers deeper in the bed are less prone to tuberworm damage.
d) *Large Tuberworm Moth Populations.* Left unchecked, tuberworm populations can become overwhelmingly huge. It is a good idea to watch tuberworm numbers during the season and make an effort to keep them in check. Waiting until vine decline or kill to attempt tuberworm control invites failure.

Growers use the following practices to manage potato tuberworm:

1) Eliminating cull piles prior to planting.
2) Choosing potato fields that are as distant as possible from previous potato plantings.
3) Planting potato tuberworm-free seed. Growers in California have found variety selection to be very important. In addition, growers check planter accuracy. Planter misses increase susceptibility to tuberworm damage, because the plants are too far apart. Growers plant seed pieces deep, with wide, flat hills. To avoid damage, they do not plant certain varieties that produce tubers higher in the hill.
4) Hilling to minimize shallow set of potatoes, and avoiding erosion of the hill by irrigation.
5) Monitoring based on pheromone trapping and scouting, during the growing season and in storage, to gauge the potential threat in each field and storage area.
6) Eliminating weedy host plants. Potatoes are the major host, but the literature documents tuberworm moths feeding on tomatoes, eggplants, peppers, tobacco, and wild solanaceous plants. Research in Oregon and Washington has not found tuberworm on solanaceous crops other than potato.
7) Rolling to seal the cracks at vine-kill, and keeping the soil moist to prevent re-cracking. This is an important practice for organic potato growers in California.
8) Reducing the amount of time between vine-kill and harvest to decrease the potential for tuberworm damage. But this has to be balanced with the need to achieve skin set.
9) Quickly transferring tubers to storage once harvesting has started.
10) Removing tuberworm-infested tubers before storing.
11) Application of the organic insecticide spinosad (Entrust), although it is not widely used by growers.

In other parts of the world, parasitoid wasps such as *Copidosoma* spp. and *Apanteles* spp. provide control. Growers in the West are not currently using or conserving these parasitoids. Common predators such as lady beetles, big-eyed bugs, and ground beetles may also provide some control, but their role is unknown.

Seedcorn maggot is a major pest in the Columbia Basin and the Klamath Basin, but it is minor in California, Colorado, Idaho, and the West of the Cascade Mountains region. It can be present at pre-emergence and can cause damage to the seed piece. Seedcorn maggot can be a problem in cool, wet seasons in high organic soils. Damage is also more likely in soil where a lot of plant debris is plowed in before planting.

Organic potato growers in the Columbia Basin shallowly plant large seed pieces in a well-prepared seedbed, and they plant sufficiently late to ensure quick seed germination. Seed pieces that are well suberized (allowed to heal after cutting) are less likely to be damaged. Growers also remove some of the hill for early weed control and to expose shoots to sunlight (blind cultivation). This likely disturbs egg-laying sites, destroys eggs via dehydration or mechanical damage, and dries out the soil surface layer. Development of the seedcorn maggot is temperature-dependent, but more research is needed to develop appropriate temperature-related management practices. Seed pieces emerge fastest at 55°F.

Recent research at Washington State University has shown that spinosad (Entrust) can be effective. Growers are currently not using this insecticide for seedcorn maggot. This is likely because they do not know about the research findings and the cost.

Wireworms are a major pest in the Columbia Basin and the West of the Cascade Mountains region, but they are only a minor problem in California and the Klamath Basin. Wireworms may be a problem in fields coming out of native vegetation or when fields were previously cropped to grass sod, pasture, wheat, corn, cereals, alfalfa, beans, onions, fallow ground, or ground not farmed for more than one year. Wireworm larvae feed on potato seed pieces and underground stems during the spring. The early feeding opens the seed pieces and stems to rotting organisms (fungi and bacteria), which then results in poor or weak stands. More serious damage occurs on developing tubers later in the season, when wireworms burrow.

Growers use their knowledge of historical wireworm infestations in a particular field as the most accurate predictor of future problems. If historical levels have been high, growers avoid planting potatoes in that field. Baits can be used to detect wireworm infestations, but numbers cannot be correlated with damage. With crop rotation, growers manage wireworms by avoiding clovers, grasses, and cereal grains. They use non-weedy alfalfa in the rotation to reduce wireworm population levels. Birds, carabid and staphylinid beetles, entomopathogenic nematodes, and entomopathogenic fungi such as *Beauveria* sp. and *Metarhizium* sp., are known natural enemies.

Dry field conditions help reduce wireworms, so some growers fallow their fields and let them get very dry. This can be problematic, though, if weeds are not totally controlled on the fallow field. Weeds may become viable plant hosts, and even though the fields are very dry, these plant hosts can keep wireworms alive.

Initial research has shown that spinosad (Entrust) and the fungus *Metarhizium* may be effective, but more work is needed. Initial research has indicated that chopped and incorporated green manure crops may also provide control. Italian researchers have shown that the incorporation of mustard green manure (*Brassica juncea*) reduced wireworm levels in potted plant studies (Furlan et al., 2004). Relatively high rates of compost (24 tons per acre) were shown to reduce wireworm damage in a study conducted on potatoes in Hermiston, Oregon.

The following insects are minor pests of organic potatoes in the West:

Grasshoppers are a minor, occasional problem in Idaho. Grasshoppers enter potato fields from uncultivated areas. Usually, population levels are small and damage is inconsequential. They can become a problem in outbreak years by defoliating potatoes, transmitting viruses, and causing spindle tuber and unmottled curly dwarf. Grasshoppers lay their eggs slightly below the soil surface in late summer or fall. Management includes proper selection of field location and tillage to expose overwintering egg pods. *Nosema locustae* (Semaspore bait, Nolo Bait) is a protozoan native to North America and infects grasshoppers, but growers are not currently using this.

Loopers, armyworms, and **cutworms** are members of a diverse, multispecies complex of lepidopterous caterpillars. These worms are an occasional problem at post-emergence. They either cut off stems at or below ground level or strip the foliage during the growing season. Some defoliation from cutworms (10–15%) can generally be tolerated. They also feed on tubers that are exposed to the surface or are accessible through cracks in the soil.

Management at preplant includes irrigation, to bring cutworms to the surface, followed by a tillage operation. Weed control in previous crops and along field edges also aids in cutworm control by reduction of early season host plants. Management includes the conservation of natural predators and parasitoids. Organic insecticides, including Pyrethrins (PyGanic), spinosad (Entrust), *Bacillus thuringiensis* (DiPel, subspecies *kurstaki*, strain ABTS-351; Biobit, subspecies *kurstaki*), azadirachtin (Aza-Direct), and soap (potassium salts of fatty acids) (Safer, M-Pede), are available but not commonly used.

Slugs are a minor, occasional problem in the West of the Cascade Mountains region. They cause injury by rasping the tissues from the leaf surfaces and stems. Slugs lay eggs year round under dirt clods and in weedy areas. Management includes sanitation. At post-emergence, iron phosphate bait is used.

Spider mites are a minor, occasional problem in all growing regions, but when they occur they can be severe. Certain crops such as beans, corn, alfalfa, clover seed, and mint tend to harbor mites. If these crops are in proximity to potato fields, mites subsequently move to potatoes when these crops mature and dry. Nearby dusty roads and hot, dry weather also contribute to spider mite outbreaks. Management includes sprinkler irrigation to makes the conditions less favorable and conservation of natural predators and parasitoids.

Symphylans are an occasional problem in the West of the Cascade Mountains region and in the Delta region of California. Symphylan feeding on the root hairs of potato may stunt plant growth before tuber formation. Symphylans damage tubers with tiny holes in the skin and an undercut cavity. Growers use field history to predict symphylan damage.

Summer flooding for three weeks can reduce symphylan populations in the soil. Thoroughly tilling the soil in the spring before planting provides some control.

Western spotted cucumber beetle (larva) is an occasional problem in the West of the Cascade Mountains region, but it is not found in California, Colorado, or Idaho. Larvae could be affecting tubers, but research is needed. Feeding injury resembles damage caused by flea beetle larvae. Elimination of weedy areas around the field may help reduce the number of overwintering sites for adults, although adults can readily disperse into adjoining fields in the spring. Row covers are used post-emergence.

False chinch bugs occasionally move into a wide range of irrigated crops, including potatoes. Migrations usually occur during hot weather when the insects migrate from drying weeds, particularly winter annual mustards. False chinch bugs cause little damage but may occur in large masses in some localized areas of a field, producing plant wilting.

Critical Needs for Management of Insects in Organic Potatoes in the Western United States

Research

- Research the biology, ecology, and control of potato tuberworm, potato flea beetles, wireworms, and Colorado potato beetle.
- For both the processing and fresh markets, continue research into potato varieties that are resistant to the major insects affecting organic potato production in western states.
- Test the residue management theory (e.g., plant into high biomass, no-till, rolled cover crops) for insect management, especially flea beetles.
- Research the use of straw mulch and the amount needed for aphid, Colorado potato beetle, and tuber flea beetle management.
- Determine how to correlate wireworm density in the soil with tuber damage.
- Research what kind of damage slugs, symphylans, and western spotted cucumber beetle larvae are causing.
- Research the efficacy of biological products for insect control.
- Research the efficacy of biological control methods for insects, including the use of lady beetles, lacewings, nematodes, and fungi (e.g., *Beauvaria bassiana*).
- Continue research on the release and conservation of beneficial insects in organic potatoes, including the use of farmscaping and insectary plant species under different conditions like dryland production.
- Research the efficacy of botanical products for seed treatments.
- Identify alternative organic insecticides to prevent resistance.
- Research the efficacy of insect repellents.
- Research the integration of cover crops into potato production, including the effectiveness of overseeding (aerially seeding) cover crops before harvest. (Seed would be planted during harvest operation.)
- Research compost teas and their effectiveness in insect management.

- Research the efficacy of oil of rosemary, clove, and thyme (Ecotrol) on green peach aphid (GPA).
- Research parasitoid species that prey on the main insect pests of organic potatoes.
- Research the temperature-dependent timing of seedcorn maggot management methods.
- Research efficacy of spinosad (Entrust) and the fungus *Metarhizium* in the management of wireworms.
- Research the use of compost for wireworm control.
- Research mustard and other similar plants as biofumigants and mustard seed meal as a treatment for wireworms.
- Research ways to avoid using broad-spectrum organic insecticides in order to conserve natural enemies.
- Research whether beetle banks can be beneficial for insect management in organic potatoes.
- Research ways to make Bt applications easier and whether Bt can be applied as a microbial inoculant.
- Research effectiveness of garlic oil spray mix as an insect repellent.
- Research efficacy of spinosad (Entrust), pyrethrins (PyGanic), and azadirachtin (Aza-Direct) for control of tuber flea beetles.
- Research parasitoid wasps, *Copidosoma* spp. and *Apanteles* spp., which are used in other countries, lady beetles, big-eyed bugs, and ground beetles for the management of potato tuberworm.
- Examine potato cultivars to identify those that are more resistant or tolerant to effects of potato psyllid injury.
- Dedicate university or farmers' land for organic potato production research, to be managed organically for the long term.

Regulatory

- Register biological materials as pesticides for use in organic potatoes.
- Register an Organic Materials Review Institute (OMRI)-approved *Bacillus thuringiensis* for Colorado potato beetle (CPB).
- Approve pending biological control agents for use in organic potatoes. Encourage Natural Resources Conservation Service (NRCS) to provide cost share money for insectary strips to increase the presence of beneficial insects in organic potatoes.
- Address state rules on seed potato production areas so that growing organic potato seed is allowed as long as it does not jeopardize conventional seed production. Organic seed may have to be grown in isolated areas away from Potato Seed Management Areas.
- Advocate for increased funding for NRCS's Conservation Security Program (CSP) and increased support for organic practices.
- Provide incentives (through NRCS) for longer rotations.
- Reduce potential conflicts between USDA's National Organic Program (NOP) standards and GAP (Good Agricultural Practices).
- Encourage USDA to provide additional funding for organic research.

Education

- Educate growers about the importance of scouting, correct insect identification, and diagnosing insect-caused tuber damage.
- Educate growers about biology and Best Management Practices (BMPs) for potato tuberworm, including management methods at planting (e.g., planting depth, planting accuracy, and reduction of aerial tubers).
- Educate growers about the effectiveness of trap crops, such as for the control of CPB and tuber flea beetle.
- Educate growers on the effectiveness of sulfur dusts in the management of potato psyllids.
- Educate growers about the use and enhancement of beneficial habitat to increase populations of birds and bats that eat insects.
- Educate NRCS about providing CSP and Environmental Quality Incentives Program (EQIP) funds for pest management practices.
- Educate growers about funding possibilities with NRCS, including cost shares for beneficial insectary strips.
- Educate growers about the use of parasitoids.
- Educate seed producers about organic seed production, the varieties that organic potato growers want, and the need for high quality, certified organic seed.
- Educate growers about the seed certification process, the difference between certification and shipping point inspections, and how growers should work with the process.
- Educate organic growers about organic research and new insect management for organic potatoes being done by university researchers.
- Educate growers, extension personnel, and other industry personnel about regulatory issues (e.g., NOP standards, seed certification).
- Educate extension personnel about how best to distribute information to organic potato growers.
- Provide accessible, Web-based pest management information for organic potatoes, including an online clearinghouse for research data (potentially an eXtension Web site for organic potato growers) and organic potato pest management electronic mailing lists.
- Provide a regional newsletter containing pest management information for organic potato growers.
- Educate organic potato growers about the resources provided to them by PotatoNet at Oregon State University and the electronic mailing list run by Oregon Tilth. (Postings are very infrequent.)
- Develop a list of organic growers in the region for dissemination to researchers at the five universities so they can get information out to organic growers.
- Develop a list of organic seed suppliers.
- Develop a list of heirloom potato varieties, detailing their advantages and disadvantages.

- Educate university researchers about the need for dedicated organic research land.
- Create a regional organic work group for research activities (e.g., through the Western IPM Center).
- Educate growers and agriculture professionals about how to convey organic farming issues to legislators (i.e., lobbying).

Disease Management
Including Vine-Kill and Postharvest Issues

Important diseases of organic potatoes grown in all western states are bacterial ringrot, black dot, common scab, early blight, early die (Verticillium wilt), Fusarium dry rot, late blight, potato virus Y (PVY), Rhizoctonia/black scurf, and silver scurf. Additionally, black leg-soft rot complex, charcoal rot, pink rot, purple top mycoplasma, Pythium leak, powdery scab, southern blight, and white mold are serious diseases in only some of the organic potato growing areas in the West.

Diseases are managed with several of the foundation practices described in the Introduction. The descriptions below are specific to disease prevention and management.

Rotation
Organic potato growers maximize the number of years between potato crops and related crops, such as tomato and eggplant, to help manage some soilborne potato diseases. Additionally, growers select rotational and cover crops that are not alternate hosts for diseases that target potatoes. Careful attention is also given to improving soil quality throughout the rotation. This improves aggregation for increased moisture retention when the soil is dry and infiltration when it is wet, and it reduces stress- and moisture-related disease incidence. Also, good rotations help produce healthier plants that are more resistant to disease. Organic growers also increase their soil organic matter content during the rotation to help with the suppression of some soilborne diseases.

Avoidance
Growers select fields with low or no level of soilborne or foliar disease inoculum. This is accomplished through knowledge of their field history, soil sampling, or both. Growers also look for fields with good drainage, good soil structure, good texture, and isolation from nearby sources of aerial inoculum (spores), such as those that cause late blight.

Sanitation
The sanitation of planters, seed-cutting equipment, harvesting equipment, storage facilities, and personnel is very important to organic potato growers in order to prevent disease introduction and spread.

Variety Selection
Some growers select varieties that have resistance to the diseases that are prevalent in their growing region, for example Defender for late blight. Growers are interested in increasing the number of varieties available and their acceptance within the marketplace.

Planting Methods
Organic growers properly cut their potato seed, allow the seed to heal or "suberize," and store seed at appropriate temperatures to minimize cuts, wounds, and bruising. Some growers also use whole seed as a method to limit susceptibility to disease infection and spread (during cutting and planting.) They pre-warm seed, and they plant seed that is warmer than the soil temperatures. Growers also plant at the appropriate depth to minimize disease issues. To minimize the duration of leaf wetness, some growers plant

with wider row spacing and orient rows to the direction of prevailing winds. But planting potato rows in the direction of the wind may increase soil erosion and damage to plants caused by blowing soil. The benefits of wider row spacing for disease management have to be balanced with the possibility of increased weed competition and heat stress on developing tubers.

Certified Seed

Organic potato growers plant high quality, early generation, certified seed in order to manage diseases. Certification of seed does not guarantee that the seed potatoes are disease-free, but rather that the disease levels fall within certain tolerable levels. Certification means that seed potatoes have met the standards of a grower-supported state certification agency. Seed purchased from different states and countries are subject to different certification rules. As such, each certification agency has its own set of tolerances, or allowable amounts, for each disease.

Green Manure Incorporation

Some organic farmers use green manure crops to help with their disease management. They plant and incorporate these cover crops for a number of reasons, including disease management, but the extent of control is not known.

Crop Residue Management

Growers manage their potato and rotational crop residues to reduce disease spread. Potato vines are destroyed to improve skin set, resulting in fewer opportunities for disease organisms to colonize the tubers. Some growers burn vines to reduce the ability of some potato pathogens to infect and survive in stem material, since these infections may produce spores that can infect future potato crops. All growers destroy cull piles before the growing season to remove inoculum sources.

Weed Host Control

Weed control is especially important in disease management in order to reduce virus infection. Growers control weeds that host insect vectors and viruses. Examples include nightshade, prickly lettuce, and others that host tobacco rattle virus. Volunteer potatoes are also destroyed as part of disease management. Hairy nightshade control is important, because it is a host for early blight, late blight, and powdery scab.

Irrigation management

Irrigation system maintenance and irrigation timing are important for disease management in organic potatoes. Organic potato growers select the time of day and the frequency of irrigation in order to reduce the duration of leaf wetness and water ponding in the field. Irrigation management is extremely important for controlling late blight and has the potential to reduce early die and common scab development. Proper equipment maintenance, including repair of leaks, is an important way to prevent areas of excess water that can also lead to leaching of nutrients and unhealthy plants.

Nutrition management
Growers manage nutrients through soil testing and appropriate fertilization in order to support healthy plants. A balanced nutrient program will reduce the impact of some diseases, but excessive vine growth with too much fertility can increase white mold, foliar black leg, late blight, and early blight. Potassium deficiency can also enhance certain pathogens.

Harvest and Storage Methods
Harvest is an important time for managing potato diseases, especially for potatoes going into storage. Proper irrigation before harvest and storage reduces impacts related to bruising and subsequent disease development (e.g., pink rot and Pythium leak) and spread. Growers select harvest dates when soil temperature, moisture, and tuber pulp temperature are at their optimum to reduce tuber damage and the likelihood of some diseases. Growers also cure and store potatoes in high humidity and warmer temperatures to maximize quick healing of wounds that occurred during harvest. Then growers reduce temperatures and humidity as low as possible given the end use (e.g. fresh market or processing) to minimize disease spread.

Compost
Organic potato growers apply compost primarily as a nutrient source, but there is increasing interest in trying to understand the role that compost may play in managing diseases.

Compost tea
Some growers apply compost teas, although they are extremely variable and not well characterized. Compost tea is thought to manipulate the organisms on the potato leaf surface and play a role in disease management. More research is needed.

Biological control
Some organic growers apply *Bacillus* formulations (Serenade) for disease management.

The following are important diseases of organic potatoes in the West:

Viral diseases:
Potato Mosaic Virus, caused by *Potato virus Y* (PVY) and other viruses, is a major disease problem of organic potatoes in all growing regions of the West. Infected seed is the primary inoculum source, along with volunteer potato plants and some weed hosts. The virus is primarily vectored by aphids, but it can also be mechanically transmitted through wounds by contact with equipment that is carrying inoculum. Infections cannot be prevented, since aphids can bring the virus into a field and quickly transmit the virus. PVY from seedborne infection causes substantial yield reduction, and the PVY strains cause both yield and quality issues (e.g. internal necrotic symptoms). Current season infection, by aphids, can also cause yield reduction.

Since infected seed is the primary source of the disease, growers plant high quality, certified seed. Some growers also select resistant varieties, such as resistant Bannock

Russet and moderately-resistant Ranger Russet and Umatilla Russet (*Potato Production Systems*). Growers generally avoid planting varieties that show susceptibility.

Some European specialty varieties also show some resistance. Latona is a yellow-fleshed, fresh market Dutch variety that has been used in California. PVY symptoms were not seen until the end of the season and did not result in any yield losses. Potato growers also manage potato mosaic by controlling volunteer potatoes and weed hosts. Aphid vectors are managed to reduce infection (see "Insects" section). Some growers surround their potato crop with a trap crop so that the virus gets discharged before aphids move into the field (nonpersistent transmission).

Purple top is a symptom caused by a phytoplasma and can be a major problem in the Columbia Basin. The disease is also called beet leafhopper-transmitted virescence agent (BLTVA), which first appeared in the early 2000s and is transmitted by the beet leafhopper (*Circulifer tenellus*). Once adult leafhoppers are infested, they can transmit the phytoplasma for life. While potatoes are not a preferred host, beet leafhoppers move into green potato fields when nearby hills dry out in summer. Substantial feeding time is needed for transmission. Leafhoppers feed long enough to transmit the phytoplasma, but they typically do not reproduce on potato. If plants are infected early, no tubers are produced. In later-infected potatoes, the pathogen survives in seed potato tubers. Normal plants may emerge from tubers grown from infected plants. Or, infected tubers may fail to sprout or may produce thin, non-viable sprouts known as hair sprouts. Recent research by USDA-ARS in Prosser, Washington, has found the following: all phytoplasma-infected plants of Ranger Russet, Shepody, Russet Norkotah, Atlantic, Russet Burbank, and Umatilla produced phytoplasma-infected tubers; 68% of phytoplasma-infected plants produced some infected tubers; and 35% of infected tubers gave rise to infected daughter plants.

To potentially reduce infection, growers can plant potatoes after the major beet leafhopper flights in early June. But reduced infection depends on the population numbers decreasing by the time plants emerge. Leafhoppers prefer many common weed hosts over potato, so growers attempt to keep fields and surrounding areas free of weeds. This reduces populations and reduces the number of leafhoppers that overwinter or acquire the phytoplasma by feeding on infected weed hosts.

Bacterial diseases:

Bacterial ring rot (*Clavibacter michiganensis* subsp. *sepedonicus*) is a major concern in all organic potato growing regions in the West. The bacterium is usually seedborne, but healthy seed can also be infected by contaminated seed-cutting machines, seed-handling equipment, truck beds, and storage facilities. There is zero tolerance for ring rot in certified seed, so this has reduced pathogen spread. Ring rot inoculum can survive on walls, floors, agricultural machinery, or nearly any surface where contact with infected potatoes has left dried bacterial slime during transporting, cutting, harvest, and storage.

Growers manage bacterial ring rot by planting quality, certified seed. Ring rot bacterial spores cannot survive in moist soil for more than one year. If ring rot has occurred on the farm, growers thoroughly clean and disinfect all storage facilities and equipment.

Black leg-soft rot disease complex (*Pectobacterium carotovora* subsp. *atroseptica* and/or subsp. *carotovora* and others) is a major disease in California and occasionally a problem in Idaho, the Columbia Basin, the Klamath Basin, and the West of the Cascade Mountains region. There are numerous inoculum sources, including primarily contaminated seed. Soil is also a potential source. Above-ground infection that is not associated with the seed also occurs, and the source of this infection is likely irrigation water.

Growers plant quality, properly stored, certified seed. Growers also warm the seed, so it is warmer than the soil temperature at planting. To encourage good airflow, growers prevent lush foliage growth. Additional management practices include avoiding wounding, controlling other foliar diseases, minimizing leaf wetness, and avoiding overwatering of potato fields (especially during periods of warm temperatures). Growers also track and control Colorado potato beetle movement, because the beetle can move the disease through the field. Growers harvest when conditions are dry and cool and avoid damaging tubers. Tubers are stored at cool temperatures to avoid breakdown from this disease during storage. Storage facilities are ventilated, and proper airflow is maintained.

To absorb excess moisture, growers treat seed with untreated fir or alder bark before planting. (This prevents seed pieces from sticking together.) Application of fir bark has been used successfully in combination with suberizing the cut seed to reduce disease incidence. Air must be passed through the pile of cut seed to insure there are no wet pockets. By managing moisture of the fresh cut seed pieces, growers are changing the conditions to reduce seed piece decay.

Only a few organic potato growers use StorOx (hydrogen peroxide/peracetic acid mixture), which is registered for use postharvest and for disinfecting equipment. The efficacy of StorOx on soft rot in storage has not been shown.

Common scab (*Streptomyces scabies*) is a major disease in all organic potato growing regions in the West except the Klamath Basin. Soil is the inoculum source. Common scab does not impact yield, but it impacts appearance and can drastically reduce attractiveness for the fresh market.

Growers select fields that have not had past problems with common scab. They also plant high quality, certified seed that is free of common scab infection.

Varieties with some tolerance to scab are available. There are also varieties that are more susceptible. The rankings below come from several resources and vary according to different areas, soil conditions, and ranking criteria. References used include *North American Potato Varieties* by The Potato Association of America, *Potato Production Systems,* various Washington State University and Oregon State University publications about varieties, and Potato Variety Information from USDA publications.

- Alturas – moderately susceptible to moderately resistant
- Atlantic – susceptible

- Bannock Russet – resistant
- CalWhite – moderately susceptible
- Century Russet – resistant
- Centennial Russet – susceptible
- Chieftain – moderately susceptible to moderately resistant
- Chipeta – moderately susceptible to susceptible
- Defender– susceptible
- Gemchip – susceptible
- Gemstar Russet – moderately resistant to resistant
- Goldrush – moderately resistant
- HiLite Russet – highly tolerant
- IdaRose – moderately susceptible
- Ivory Crisp - susceptible
- Katahdin – susceptible
- Kennebec – very susceptible
- Klamath Russet – resistant
- Lemhi – highly tolerant
- NorDonna – moderately resistant
- Norland – moderately resistant
- Norkotah – some tolerance
- Umatilla – moderately resistant to resistant
- Ranger Russet – moderately susceptible to susceptible
- Red La Soda – moderately susceptible to susceptible
- Russet Burbank – tolerant to moderately resistant
- Western Russet – tolerant
- White Rose – susceptible
- Yukon Gold – moderately susceptible to susceptible

The most important common scab control for organic growers is to provide adequate and even moisture during tuber initiation and early development. In the California growing region some growers use green manures to help reduce common scab. The green manure is thought to increase microbial activity in the soil, thus competing with the disease-causing organism.

Fungal diseases:

Black dot (*Colletotrichum coccodes*) is a disease found in all organic potato growing regions in the West, especially the Columbia Basin. This disease is soilborne and seedborne. It invades plant roots from the soil or leaves via windborne spores, particularly where damage is caused by blowing sand. Black dot can cause yield reductions and quality issues from surface infection of fresh market and processing tubers. Many fields have the disease, but growers do not realize it. Careful diagnosis is important, since black dot can be confused with Verticillium wilt in the field and silver scurf on tubers in storage.

Growers plant quality, certified seed and rotate to potatoes no more frequently than every 4 or 5 years. They also promote even, consistent plant growth and reduce stress by improving soil quality and providing consistent nutrient and moisture supply.

Charcoal Rot (*Macrophomina phaseolina*) is a major disease only in California, during long, hot summers. Charcoal rot affects many different vegetable crops in warm growing regions. Infections normally begin on stems and roots of potato plants but progress onto the tubers.

Growers plant fields known to be infested with charcoal rot early to avoid growing the crop during the heat. They also select early-maturing varieties and harvest as soon as the crop matures.

There are no known organically-approved chemicals for control of charcoal rot. Biological seed treatments with T-22 Planter Box (*Trichoderma harzianum*) and others may show some benefit, but they have not been studied.

Early blight (*Alternaria solani* and *alternata*) is a major disease of organic potatoes in all regions of the West**.** The fungus overwinters in host plant debris, soil, infected tubers, and other solanaceous plants. Early blight appears as dark brown to black lesions on leaves and stems, and it can infect tubers. If infections occur early in the season, yield loss can be significant.

Growers select fields that have not had potatoes for several years, are isolated from inoculum sources, and have good soil drainage. Fields are designed to minimize the duration of leaf wetness (e.g., wide row spacing and row orientation in the direction of prevailing winds). Growers also plant high quality, certified seed, of varieties with resistance.

The rankings below come from several resources and vary according to different areas, soil conditions, and ranking criteria. References used include *North American Potato Varieties* by The Potato Association of America; *Potato Production Systems,* various Washington State University and Oregon State University publications about varieties and Potato Variety Information from USDA publications.

- Alturas – foliar-resistant; moderately tuber-resistant
- Atlantic – foliar-susceptible; tuber-resistant
- Bannock Russet – moderately foliar-resistant; moderately tuber-resistant
- CalWhite – foliar-susceptible; moderately tuber-resistant
- Chieftain – moderately foliar-susceptible; moderately tuber-resistant
- Chipeta – moderately foliar-susceptible; tuber-resistant
- Defender – tuber-resistant
- Gem Russet – moderately foliar-susceptible; tuber-resistant
- IdaRose – moderately foliar-susceptible; tuber-resistant
- Ivory Crisp – foliar-susceptible; moderately tuber-resistant
- Kennebec – foliar-resistant
- NorDonna – foliar-susceptible; tuber-susceptible
- Norland – foliar-susceptible; moderately tuber-resistant
- NorValley – foliar-susceptible; tuber-resistant
- Ranger Russet – moderately foliar-susceptible; moderately tuber-susceptible
- Red La Soda – foliar-susceptible; tuber-susceptible
- Russet Burbank – moderately foliar-susceptible; moderately tuber-resistant
- Russet Norkotah – foliar-susceptible; moderately tuber-resistant

- Sangre – moderately foliar-susceptible; moderately tuber-resistant
- Sebago – foliar-resistant
- Shepody – foliar-susceptible; moderately tuber-resistant
- Umatilla Russet – moderately foliar-susceptible; moderately tuber-resistant
- Yukon Gold – foliar-susceptible; moderately tuber-resistant

Growers also manage early blight by providing consistent, balanced nutrition and moisture to reduce plant stress. They are careful to not under fertilize with nitrogen, and they minimize splashing of rain and irrigation water from soil to plant surfaces. Growers do not harvest when vines are green or when tubers are immature or wet. Early blight is also managed by minimizing wounding of tubers during harvest. Before storage, growers inspect potatoes and remove all diseased tubers. They also regularly scout potatoes in storage.

If necessary, some organic growers apply copper fungicides that meet the national organic standards (e.g., copper hydroxide, cupric oxide, copper octanoate, Bordeaux mix). Growers use disease forecasting to time these sprays. OxiDate (hydrogen peroxide/peracetic acid mixture) is available for in-field application, but growers did not report using this product. StorOx (hydrogen peroxide/peracetic acid mixture) is available for use in storage, and at this time it is not widely used by growers.

Early dying (*Verticillium dahliae* alone or in interaction with *Pratylenchus penetrans*, root lesion nematode) is a major disease in Colorado, Idaho, the Columbia Basin, and the Klamath Basin, but it is only a minor disease in California and the West of the Cascade Mountains region. Inoculum sources include infested soil or infected seed. Plants show early yellowing, typically on lower leaves, and usually first on sandy ridges. Early dying results in significant yield reduction.

Growers select a field with no or low levels of either *V. dahliae* or *P. penetrans,* and they plant potatoes only every 4th or 5th year. Growers also plant high quality seed of varieties that have some resistance to early dying, including Alturas, Bannock Russet, Chipeta, IdaRose, Ranger Russet, and Sangre. Growers improve soil quality and provide consistent, balanced nutrition and moisture to reduce plant stress. They avoid over-irrigating, especially early in the season when *V. dahliae* infection occurs, and they reduce water applications as much as possible prior to tuber set. Researchers in Washington are studying whether high biomass cover cropping (using select green manures, such as sudangrass, mustards, or rapeseed) suppresses Verticillium wilt incidence.

Fusarium dry rot (*Fusarium sambucinum* or *coeruleum* and many others) is a major disease in all organic potato growing regions in the West. Inoculum is located in soil and infected seed. Infection can occur through wounds inflicted during harvest and handling and through exposed surfaces of cut seed. This disease can cause major losses of stored potatoes. Seed infection can affect stand establishment.

Organic potato growers plant quality seed and do not use seed with known dry rot infections. Growers clean and disinfect all handling, cutting, and planting equipment between each seed lot. Some growers also suberize seed to help prevent rot in seed.

If growers cut seed, some treat the seed with T-22 Planter Box (*Trichoderma harzianum*). While T-22 Planter Box has been successfully used in California and seems to work on *Rhizoctonia*, growers in other areas have found variable efficacy. Growers wonder if results are dependent on soil types. There is currently no information about the efficacy of T-22 Planter Box use on *Fusarium* or *Pythium*. OxiDate (hydrogen peroxide/peracetic acid mixture) is available for seed treatment, but growers did not report using this product.

A few growers are using Bio-Save 10 LP (*Pseudomonas syringae*) to treat potatoes in storage. Research has shown that Bio-Save 10 LP reduces Fusarium dry rot.

StorOx (hydrogen peroxide/peracetic acid mixture) is also labeled for dry rot control in storage, but it is not widely used at this time.

Late blight (*Phytophthora infestans*) is a major, but sporadic, disease in all organic potato growing regions in the West. It is rare in the Klamath Basin. The fungus overwinters in potato seed, cull piles, and volunteer tubers. Late blight can cause significant losses in the field and in storage.

Growers select fields isolated from inoculum sources and that have good airflow and soil drainage. They also plant high quality seed, free of late blight. Resistant varieties are an option for growers, such as Defender and Jacqueline Lee for the fresh market and Defender for processing. Growers avoid compaction, destroy hosts (volunteer potatoes, cull piles, and susceptible weeds such as the nightshade species), and design fields to minimize the duration of leaf wetness (e.g., wide row spacing and row orientation in the direction of prevailing winds). They also select the appropriate irrigation systems, maintain these systems to prevent leakage, and select the time of day and frequency of irrigation to reduce the duration of leaf wetness and water ponding in the field. Growers avoid planting in low areas of fields or where overlaps of irrigation systems occur. They destroy early infections by spot flaming or flailing, maintain high hills without cracks, roll and seal cracks in the soil at vine-kill, and ensure that vines are completely dead before harvesting. Before storing potatoes, growers inspect them and remove all tubers that exhibit signs of frost damage or early stages of rot. They cool tubers immediately once healing has occurred after harvest, and they store tubers at cool temperatures, with proper ventilation to avoid pressure bruising or water loss.

Growers use disease forecasting to time organically-approved fungicide sprays. They use copper fungicides that meet the national organic standards (e.g., copper hydroxide, cupric oxide, copper octanoate, Bordeaux mix). A grower in the Columbia Basin has used sulfur. OxiDate (hydrogen peroxide/peracetic acid mixture) is available for in-field application, but growers did not report using this product. StorOx (hydrogen peroxide/peracetic acid mixture) can be used in storage, but it has not been widely used in storage for late blight.

Pink rot (*Phytophthora erythroseptica*) is a major disease in Colorado, Idaho, and the Klamath Basin. It is a minor problem in the Columbia Basin. Fungal spores overwinter in the soil and then germinate and infect stolons, eyes, and lenticels. Pink rot can cause significant losses in the field, and infected tubers and secondary infections can cause problems in storage.

Growers rotate at least 5 years between potato crops. They avoid over-irrigating, and they select, maintain, and manage the irrigation system to minimize soil saturation/water ponding in the field. Growers also avoid wounding during harvest, and they harvest when tuber pulp temperatures are low (< 65°F). Tubers are cooled immediately after healing occurs in storage, and tubers are stored at cool temperatures, with good air circulation. Growers regularly monitor the potatoes in storage to look for potential problems.

StorOx (hydrogen peroxide/ peracetic acid mixture) can be used in storage, but it has not been widely used in storage for pink rot. It has limited efficacy.

Powdery scab (*Spongospora subterranea*) is a major disease of organic potatoes in some production areas of the Klamath Basin, especially where they are growing red-skinned, white-skinned, and yellow-skinned varieties. It is a minor disease in all other organic potato growing regions in the West. This fungus is present in infected seed or infested soil. Cosmetic defects can lead to rejection in the fresh market. This fungus can vector potato mop-top virus (PMTV), which can cause internal necrotic issues.

Growers select a field with no history of powdery scab and plant high quality, certified seed of varieties that have resistance (e.g., russets). They grow potatoes only every 4th or 5th year. Growers also avoid over-irrigation, especially early in the season.

Pythium leak (*Pythium* spp.) can be a major disease in California and the Columbia Basin. It is also occasionally a problem in Colorado and Idaho. Fungal spores overwinter in the soil and usually infect wounds of harvested tubers. Pythium leak causes damage ranging from some tuber rot to total losses in storage. Substantial infections can occur in tubers prior to harvest, but this situation is not common.

Growers select fields based upon a field history of reduced pathogen levels. Soil sampling can also determine pathogen levels in the soil prior to planting, which may be beneficial for organic potato production.

Growers improve soil quality and increase microbial activity by adding compost, which has been shown to increase infiltration, reduce waterlogging, and reduce tuber infection through general suppression. Growers avoid wounding tubers at harvest and avoid harvesting if tuber pulp temperatures are above 65°F. They remove rotten or damaged tubers before placing them into storage. They also cool tubers immediately after healing in storage and store tubers at cool temperatures, with good air circulation. Adequate air is critical in storage, particularly early in the storage season, to insure drying of tubers, which reduces disease spread. It also to aids in wound healing.

Rhizoctonia stem and stolon infection and black scurf (*Rhizoctonia solani*) is a major disease in all organic potato growing regions in the West. The fungus is found in soil and infested seed and invades stems, sprouts, and wounds. *Rhizoctonia* can cause poor stands, weak plants, reduced yields, misshapen or cracked tubers, and blemished tubers.

Organic potato growers plant high quality, certified seed that is free of black scurf. They plant only in warm, well-drained soils, and they drag-off (remove part of the hill) and/or plant shallowly to promote rapid emergence. Growers avoid over-irrigation in damp, cool soils, especially early in the season. They also try to ensure that organic matter is completely broken down, although this is difficult. They minimize the period between vine-kill and harvest so that it is only the amount of time needed for skin set.

Some growers apply seed treatments. Growers have used the following: HeadsUp (Plant Protectants Inc.), which is a botanical extract that acts as a systemic acquired resistance (SAR) activator, T-22 Planter Box (*Trichoderma harzianum*), and saponins extracted from *Chenopodium quinoa*.

Silver scurf (*Helminthosporium solani*) is a major disease in all organic potato growing regions in the West. Infected seed pieces and infested soil are inoculum sources. Infected tubers in storage can produce spores that infect healthy tubers. Silver scurf reduces the quality of fresh-marketed potatoes and increases water loss in storage.

Growers plant quality, certified seed that is free of silver scurf. Seed can be tested prior to purchase. Growers also maintain a minimum two-year rotation between potato crops. Growers limit the period between vine-kill and harvest to just long enough to set skins.

Sanitation in storage is important. Growers clean and disinfect storage facilities. They also assay tubers from the field prior to storage to determine risk due to this disease. After healing has occurred, growers store tubers at low temperatures and controlled humidity. Lower relative humidity in storage can be used to minimize silver scurf spread, although additional weight loss will also occur. Growers avoid any movement or activity in storage, such as partial removal of the stored crop that can dislodge *Helminthosporium solani* spores and potentially spread the fungus to healthy potatoes. Certain types (thin-skinned) or varieties of potatoes may be more susceptible to silver scurf infection, both primary infection apparent at harvest and secondary infection often seen 3 or more months after storage.

Biox-C (clove oil), Bio-Save 10 LP (*Pseudomonas syringae*), StorOx (hydrogen peroxide/peracetic acid mixture), and Serenade ASO and Serenade MAX (strain of *Bacillus subtilis*) are available for use in storage. None of these products controls silver scurf in storage. They only possibly reduce the severity and incidence.

Southern blight (*Sclerotium rolfsii*) can be a major disease in California. It is seen especially in conventional fields because of short rotations. Organic growers try to avoid fields with southern blight. This fungus survives in the soil and is a common pest of many crops that are grown in warm regions. Hosts include beans, onions, carrots, melons, alfalfa, and potatoes. The disease causes rotting tubers in the field or in transit.

In fields that are known to be infested with southern blight, growers plant as early as possible or plant early-maturing varieties so that potatoes have matured before the arrival of hot weather. They keep plants green as long as possible and harvest soon after vine-kill.

There are no organically-approved chemicals for control of southern blight. Biological seed treatments, such as with T-22 Planter Box (*Trichoderma harzianum*) and others, may provide some benefit, but they have not been studied.

White mold (*Sclerotinia sclerotiorum*) is a major disease in Idaho, the Columbia Basin, and the Klamath Basin (especially where vigorous vine types are grown), and only a minor issue in California, Colorado, and the West of the Cascade Mountains region. Sclerotia, the resting structures of the pathogen, overwinter in the soil and germinate when environmental conditions are favorable (generally as rows begin to close). Infection results when spores germinate near the potato stems.

Growers select fields that have no history of this disease (including rotation crops), that are isolated from other fields with a history of this disease, and that have good airflow and soil drainage. They also avoid rotation with alternate hosts, of which there are many, and they manage weed hosts such as lambsquarters and pigweed. They plant potatoes only every 5th year. Growers select cultivars with big, open vines that do not lie down. They avoid over-fertilizing with nitrogen. Growers design fields to minimize the duration of leaf wetness (e.g., wide row spacing and row orientation in the direction of prevailing winds). Their main tool is to avoid overwatering. Growers also rely upon methods used for managing late blight to help manage white mold, including minimizing excess water on the canopy.

While not commonly used by organic potato growers, the fungal biocontrol agent *Coniothyrium minitans* (Contans) can be used to help manage white mold. Contans destroys sclerotia. Research has shown that for greatest efficacy at low disease levels, Contans should be applied to diseased residues after harvest to control the disease in subsequent potato crops. For control in the current season’s crop, growers apply Contans to soil the previous fall, as it requires from several weeks up to months to colonize and destroy the sclerotia.

A few growers use copper fungicides that meet the national organic standards (e.g., copper hydroxide, cupric oxide, copper octanoate, Bordeaux mix) and have found them to be efficacious.

The following are minor diseases of organic potatoes in the West:

Viral diseases:
Calico, caused by *Alfalfa mosaic virus* (AMV), is an issue for organic potato production in the West, but it is not a problem of significance in Idaho. Legume crops, especially alfalfa, are the hosts of the virus. This virus is spread by at least 16 different aphids, including the green peach aphid, in a nonpersistent manner. Usually only a single plant is

affected, but it can be a problem when potatoes are planted next to alfalfa or clover. Aphids move from the alfalfa field after cutting to potato fields and infect potato plants. Aphids do not transmit the virus between potato plants, but the virus can be carried in infected tubers.

Growers plant certified seed, and they avoid planting near clover or alfalfa, especially near older alfalfa fields, which are more likely to have a virus buildup.

Potato Latent Mosaic (*Potato virus X*, or PVX) is often present in organic potato growing regions in the West, but it is not really an issue for growers. The virus can be present in infected seed potatoes or volunteer potatoes. PVX can be mechanically transmitted by equipment or by people. PVX infection is usually symptomless and often of little economic importance. Most damage occurs when the plant is infected with both PVX and PVY. Severe symptoms occur resulting in a condition called"rugose mosaic." Growers plant high quality, certified seed to help manage this disease.

***Potato Leafroll Virus* (PLRV)** can be a substantial issue, but in recent years the level of this virus has been greatly reduced in seed. The virus can be present in infected seed potatoes, volunteer potato plants, and some weed hosts. PLRV is vectored primarily by green peach aphids, and secondarily by potato aphid and foxglove aphid. This virus is transmitted through feeding in a persistent manner (i.e., the aphid never loses the virus). Seedborne infection results in substantial yield reduction. Current season infection causes yield loss and net necrosis in the tuber, causing it to be unmarketable.

Growers plant high quality, certified seed of resistant clones that have minimal disease infection, including the very resistant variety Umatilla Russet; moderately resistant varieties Chieftain, Gem Russet, IdaRose, NorDonna, Norland, Russet Norkotah, and Sangre; and resistant varieties Alturas, Atlantic, Bannock Russet, Chipeta, Ivory Crisp, and NorValley (*Potato Production Systems*). Growers also control aphid vectors, volunteer potatoes, and weed hosts.

Potato Mosaic, caused by *Potato virus A* (PVA), is a minor issue for organic potato production in the West. The virus can be present in infected seed potatoes, volunteer potato plants, and some weed hosts. This disease is similar to PVY and is vectored primarily by aphids.

Growers plant high quality, certified seed. They control aphid vectors, including green peach aphid, potato aphid, or any other aphids that may probe potato plants (but that are non-potato-colonizing aphids). They also control volunteer potatoes and weed hosts. This virus is difficult to control, since it is quickly transmitted through probing in a non-persistent manner (i.e., the aphid loses the virus by probing a non-infected plant).

Fungal diseases:

Powdery mildew (*Erisyphe cichoracearum*) is a minor disease of organic potatoes in the West. Infested plant debris is the source of this fungus. Minor infection is more commonly found late-season, but occasionally major problems can occur.

Growers scout fields regularly to identify potential problems. Before infections become established, some growers apply sulfur fungicides that meet the national organic standards.

Vine-Kill

Killing potato vines before harvest is a common practice in all organic potato growing regions in the West. Killing vines 2 to 3 weeks before harvest allows the stolons to loosen from the tubers and hastens tuber maturity and "skin set." It takes 14 to 21 days for tuber skins to mature once the skin set process has started. Skin set provides a barrier to disease entry.

The mature skin is also crucial for providing a quality crop during harvesting, transportation, and storage. Mature skin is equally important for tubers that will not be stored, because it protects against bruising that can be caused by harvesting and handling and helps tubers keep longer.

Two kinds of bruising can occur. Shatter bruising is when the skin breaks apart. This is more prevalent when the tubers are more hydrated or when tubers are harvested when temperatures are cold. Black spot bruising is likely to occur when tubers are dehydrated. Cells are damaged, causing a black spot on the inside of the tuber, but no skin is broken. Mature tubers lose less water during storage, are more resistant to skinning, generally have less tuber decay, and are more resistant to shatter bruising during harvest.

Mechanical vine-killing techniques include the use of a flail-type mower (also referred to as a vine beater) to chop the vines, and vine rollers that crush the vines. Some growers flail and then flame a few days later. Leaving vines in the field until the frost kills them is also an option. This is not optimal because after the vine-killing frost, growers need to wait three weeks before harvesting potatoes to allow the skin to set or harden. There is a risk of additional frosts during this three week period that may cause frost damage to the tubers in the ground. Vines can also be allowed to senesce naturally by reducing water applications in some cultivars.

Some organic growers are interested in organically approved herbicides that could be used for chemical vine-kill and could help them attain a fast vine-kill. Organically approved herbicides are not currently labeled for this use. Growers, especially in the Columbia Basin, are also interested in the availability of a late-season herbicide that would be good for controlling vines and late-season weeds. These products need to be well researched, because some vine-kill products can cause tuber damage (i.e., tuber end discoloration).

Potatoes are removed from the soil 0 to 3 days after vine-kill or up to as long as 21 days after vine-kill. If potatoes are left in the soil any longer, silver scurf and black scurf infection can increase. The risk from potato tuberworm also increases after vine-kill.

Postharvest

Potatoes are sold fresh, 1–10 days after harvest, or are stored. Potatoes that are stored are typically cured for 2 to 3 weeks at 50–55°F for proper wound healing to occur. Final holding temperatures depend on 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.

Growers use three major management tools when storing potatoes: temperature, airflow, and humidity. All of these tools, used in various combinations, help growers store potatoes without chemical inputs. Lower storage temperatures retard sprout and disease development. Unfortunately, however, low storage temperatures are not necessarily an option for organic potato growers storing potatoes for processing. Low temperatures increase sugar development and increase the potential for unacceptable product color. Airflow management is necessary for disease management, especially in storage facilities with wet rot concerns. Lowering humidity in the storage facility can decrease some disease concerns, although weight loss and pressure bruising will be greater in return. All of these tools differ with the cultivar stored and the intended use of the potatoes.

Growers clean and disinfect all storage facilities and handling equipment prior to use. As potatoes are loaded into the storage facility, growers physically remove all wet potatoes, all vines, other debris, and excess soil. Growers either do not store potatoes, or they store them in a manner that provides a clear separation (e.g., at one end of a cellar, or in separate bins) between healthy potatoes and infected potatoes coming from areas in the harvested field where known diseases have occurred. Tuber pulp temperatures are recorded and used to determine proper ventilation and temperature regimes for removal of field heat.

Once the potatoes are placed into storage, they are cured at 50–55°F for 2 to 3 weeks, depending on the variety and the temperature at which the tubers are maintained. This curing or wound healing period allows healing of bruises, cuts, scrapes, or surface damage, if adequate temperature and a high-humidity air supply are available. Temperatures below 50°F may reduce the rate of this wound healing, thereby extending the length of storage time required to provide adequate protection to the tubers. Temperatures above 60°F may increase disease development before the wound healing process can be completed. Wound healing is an extremely important component in reducing disease spread and minimizing losses from shrinkage during long-term storage. After the wound healing period is complete, storage temperatures are lowered to the targeted holding temperature. Optimal holding temperatures for potatoes in storage depend on the potato variety and the intended end use of the product. Processing potatoes are generally stored between 44 and 50°F to limit the reduction of sugar content. By comparison, potatoes intended for fresh market may be stored between 40 and 50°F, while those intended for seed are usually stored at 37–40°F.

Although lower storage temperatures can prolong tuber dormancy, or the period where sprouts do not develop, some varieties sprout before it is time to market the potatoes. Sprouting causes increased tuber weight loss, reduces quality, and impedes airflow through the potato pile. Impeded airflow reduces the grower’s ability to manage the storage, because it increases pile temperatures and potentially increases disease problems. Physiological effects from sprouting are noticeable in the conversion of starch to sugars.

This is undesirable in the processing sector, because it causes greater fry color darkening. The visibility of sprouts on fresh pack potatoes is not acceptable to consumers.

Growers also increase or decrease potato storage temperatures to minimize disease development. Many storage disease problems are minimized by reducing the holding temperature. Dry rot caused by *Fusarium* sp. is generally reduced at lower temperatures, and, likewise, silver scurf *(Helminthosporium solani)* incidence and severity can be reduced at lower storage temperatures. However, managing a storage temperature to control or prevent the spread of disease may affect the tuber quality that is needed for processing or fresh market uses. Maintaining high relative humidity may contribute to the spread of diseases such as silver scurf in storage. The balance is to keep temperature as low as possible and humidity levels as high as possible without creating areas of free moisture, impacting tuber weight loss, etc.

Growers have access to several organically approved postharvest products that are spray-applied as potatoes are being loaded into the storage facility. Approved products include Serenade ASO and MAX (strain of *Bacillus subtilis*), Biox-C (clove oil), Bio-Save 10 LP (*Pseudomonas syringae*), and StorOx (hydrogen peroxide/peracetic acid mixture) for silver scurf control in storage. Bio-Save 10 LP is also labeled for dry rot control in storage. StorOx is also labeled for soft rot, early blight, late blight, and dry rot control, but it is not widely used. Efficacy of these products can vary greatly, from moderate to no disease reduction. Product registration does not signify successful disease control or economic return with usage. The best control of these diseases is accomplished by following recommended procedures, from buying seed that is free of these diseases to employing proper sanitation and correct harvesting procedures.

For sprout management, growers primarily use clove oil (Biox-C, Sprout Torch). Some growers use mint oil. Since these products are physically damaging (causing necrosis) to the sprout, multiple applications are necessary. In some storage environments, one product may yield greater success than another, and application inconsistencies can cause problems.

Critical Needs for Management of Diseases and Sprout Control in Organic Potatoes in the Western United States

Research

- Research the impact that organic residue amendments have on the incidence and severity of specific potato disease. Look particularly at which organic residue factors (e.g., residue source, composting, nutrient inputs, maturity/decomposition level) contribute to disease suppression, if any. When organic residues are effective, are there residue or amended-soil variables that are related to disease control efficacy (e.g., general or specific microbial populations, decomposition level)?
- Research the impact of multiyear organic amendment (manures, composts, cover crops, and sod rotation) on potato disease severity. Discover if there are specific soil variables related to suppression of specific diseases (e.g., microbial activity, general or specific microbial populations, active organic matter contents).

- Compare the effect of organic fertilizers (e.g., feather, seed meals or Chilean nitrate) versus organic residue amendments (manures, compost, green manures) on potato disease incidence and severity, especially common scab. Research whether manure application affects common scab, *Pythium*, pink rot, and *Rhizoctonia*.
- Investigate whether compost tea applications to foliage or soil impact specific potato disease incidence or severity. Define the compost tea production factors (compost source, nutrient inputs, production techniques) that contribute to disease suppression, if any. When compost tea is effective, are there compost tea variables that are related to disease control efficacy (e.g., general or specific microbial populations)?
- Investigate the effect of in-season fertility inputs on specific disease incidence and severity.
- Discover the impact of specific green manures, rotation crops and management techniques (e.g. no-till vs. flailing/incorporation, timing of crop/green manure growth and incorporation) on incidence and severity of specific diseases, especially common scab and Verticillium wilt. Does rotation crop or green manure crop/cultivar matter?
- Research the impact of short-, medium-, and long-term organic soil management on incidence and severity of specific potato diseases. Develop a method to design experiment stations and/or on-farm trials to effectively research this question.
- Research the application of *Coniothyrium minitans* (Contans) in organic potato production systems to effectively and economically manage white mold.
- Research the efficacy of approved and new organic pest management materials, including StorOx, Oxidate, and Tsunami for the black leg-soft rot disease complex.
- Breed potato varieties that are resistant to priority diseases for the processing and fresh markets.
- Investigate seed piece treatments for organic potatoes, especially to manage black scurf and early-season emergent diseases such as *Rhizoctonia*.
- Determine the comparative efficacy of the organically-allowed copper products for control of potato diseases (e.g., copper hydroxide, cuprous oxide, copper oxychlorate, copper sulfate).
- Develop forecasting models for early blight and late blight management in organic potato production.
- Continue research on the spread and control of potato viruses. Determine whether organic management or specific production practices impact potato susceptibility to viral diseases.
- Investigate new nonchemical vine-kill methods and existing and new organically-approved vine-kill products, especially for difficult-to-destroy varieties.
- Evaluate new methods to sow cover crop seed during other equipment passes across the field, e.g., broadcasting seed during harvest or postharvest operations.
- Research the optimal duration of time between vine-kill and harvest for different potato varieties.
- Determine which methods and organically-approved products should be used to sanitize storage and handling equipment.

- Determine how potato storage diseases and dormancy can be most effectively managed through the use of curing temperatures, holding temperatures, humidity, and airflow.
- Breed potato varieties that have excellent storage properties under organic management (e.g., dormancy, processing qualities and resistance to storage diseases).
- Investigate products and methods of application for sprout and disease control in storage that can be used on organic farms.
- Research which equipment and techniques are most useful for organic and/or small-scale storage management.
- Research the integration of cover crops into potato production, including the effectiveness of overseeding (aerially seeding) cover crops before harvest. (Seed would be planted during harvest operation.)
- Research the food safety and environmental aspects of pest management practices such as manures and compost teas.
- Research the biological and economic viability of the organic potato seed industry.
- Explore opportunities to produce organic potato seed in geographical areas that would not be in conflict with traditional Potato Seed Management Areas.
- Confirm the impacts of summer dry fallow on *Verticillium* levels.
- Research whether increased microbial activity has the potential to suppress late blight tuber infection.
- Dedicate university or farmers' land for organic potato production research, to be managed organically for the long term.

Regulatory

- Facilitate the introduction to the United States of disease-resistant varieties grown in other countries.
- Facilitate the registration of biologicals and other pesticidal materials that can be used on organic farms.
- Provide government funding for research on organic production and storage.
- Address state rules on seed potato production areas so that growing organic potato seed is allowed as long as it does not jeopardize conventional seed production. Organic seed may have to be grown in isolated areas away from Potato Seed Management Areas.
- Work to defend the use of copper fungicides.
- Work to get organically-approved herbicides labeled for use during vine-kill.
- Encourage USDA to provide additional funding for organic research.

Education

- Educate manufacturers of biological products about the importance of registering their products as pesticides.
- Educate chemical manufacturers about the IR-4 program for registration of biological pesticides.
- Work with growers on scouting and pest diagnosis.
- Educate the U.S. potato industry about resistant germplasm research in the European Union and other areas of the world.

- Educate growers about the availability of resistant varieties, including potato varieties with late blight resistance (i.e., Defender, Sante and Jacqueline Lee, which are new varieties). Also educate growers about resistant varieties that will be available in the future.
- Educate growers about the use of soil moisture management for the control of common scab.
- Work with growers on systems management of potato diseases such as late blight.
- Educate growers about spraying copper or other protectants before infection occurs to control foliar diseases, especially late blight.
- Educate growers about the necessary elapsed time between vine-kill and harvest for certain varieties, and the impact of early and late harvest on specific diseases (e.g., black scurf, scab, and tuber rots).
- Provide information to growers about the sanitation of storage and handling equipment and why it is important.
- Educate growers on the use of temperature, humidity, and airflow for storage disease control.
- Educate growers about proper storage temperatures for each variety and end-use.
- Educate growers about the storage characteristics of different varieties.
- Provide information on how to maximize the use of current storage equipment.
- Educate growers about the proper use of and expectations about postharvest products approved for use on organic farms.
- Educate growers about ways to reduce *Pythium* levels.
- Educate seed producers about organic seed production, the varieties organic potato growers want, and the need for high quality, certified organic seed.
- Educate growers about the seed certification process, the difference between certification and shipping point inspections, and how growers should work with the process.
- Educate organic growers about organic research being done by university researchers.
- Educate growers, extension personnel, and other industry personnel about regulatory issues (e.g., NOP standards and seed certification).
- Educate extension personnel about how best to distribute information to organic potato growers.
- Provide accessible, Web-based pest management information for organic potatoes, including an online clearinghouse for research data (potentially an eXtension Web site for organic potato growers).
- Provide a regional newsletter containing pest management information for organic potato growers.
- Educate organic potato growers about the resources provided to them by PotatoNet at Oregon State University and the electronic mailing list run by Oregon Tilth. (Postings are very infrequent.)
- Develop a list of organic growers in the region for dissemination to researchers at the five universities so they can get information out to organic growers.
- Develop a list of organic seed suppliers.
- Develop a list of heirloom potato varieties, detailing their advantages and disadvantages.

- Educate university researchers about the need for dedicated organic research land.
- Create a regional organic work group for research activities (e.g., through the Western IPM Center).
- Educate growers and agriculture professionals about how to convey organic farming issues to legislators (i.e., lobbying).

Weeds

The following weed management information is based upon the publication, *Managing Weeds in Organic Potato Production*, by Rick Boydston, USDA-ARS, Prosser, Washington.

Organic potato growers manage weeds by using a combination of tactics. Multiple control methods and a diverse crop rotation are used to deter the buildup of a few difficult-to-control species. Specifically, organic potato growers use the following practices to manage weeds:

1. Diversified crop rotation to prevent certain weed species from becoming dominant. If possible, growers include both summer annual and winter annual crops in the rotation, or fall-planted green manure or cover crops. Growers use different crops in the rotation to eliminate "windows of opportunity" for weeds to germinate and establish during the same periods year after year.

2. Use of green manure or cover crops to compete with weeds, prevent weed establishment, and prevent new weed seed addition to the soil seed bank. Cover crops have many other advantages, such as nitrogen fixation, disease and nematode suppression, prevention of soil erosion, addition of organic matter to the soil, and reclamation of nutrients. According to the literature, cover crops that have reportedly suppressed weeds and have potential for use in organic production include: rye, oats, rapeseed, mustards, barley, sudangrass and buckwheat. Rye, oats, rapeseed, and white or brown mustard release allelopathic compounds that can inhibit weed germination when they are incorporated into the soil. Barley, sudangrass, and buckwheat grow rapidly and can out-compete many weeds. Cover crops that have been used by growers in the West specifically prior to organic potatoes include: sudangrass, mustards (*Sinapis alba*, *Brassica juncea*), buckwheat, and oat-legume mixtures (oats, vetch and peas). Growers using sudangrass cover crops are aware of which varieties suppress nematodes and which ones are actually hosts to plant pathogenic nematodes. Weeds can become an issue in the cover crop. If time permits, growers reduce the weed seed bank by irrigating to induce a first flush of weeds, and then destroying them with flaming or shallow cultivation (stale seedbed technique, see below) prior to planting the cover crop.

3. The use of a stale seedbed is a technique in which ground is prepared in advance of seeding the crop and irrigated to promote an early flush of weeds that are then removed before the crop is emerged or planted. This requires additional time and irrigation water to prepare the ground, irrigate and destroy weeds that emerge. Weeds can be destroyed by shallow cultivation or flaming before the crop emerges, although growers do not commonly use flaming. The advantage of flaming over cultivation is that it does not bring new weed seeds to the surface where they can germinate. However, the operation of planting potatoes disturbs the soil, so the advantage conferred by flaming is lost during planting. In addition, flaming gives poor control of grass weeds.

4. Planting techniques and cultivar selection. Growers select competitive crop cultivars and critical crop-sowing dates to avoid specific weed germination periods and to ensure rapid and uniform crop emergence. Indeterminate potato varieties (e.g., Russet Burbank, Ranger Russet, Alturas, Century Russet, Russet Nugget, German Butterball) tend to produce larger canopies that close sooner and compete with weeds better than determinate varieties (e.g., Russet Norkotah, Red Lasoda, Red Norland, HiLite Russet, Silverton, Sangre, Yukon Gold, Durango Red). Growers also plant at the correct temperature and depth and avoid planter skips to encourage quick emergence. The planter also kills some weeds. In addition, growers choose varieties that quickly produce a full canopy and maintain it as long as possible. Some varieties produce a quick canopy but then fall flat, which allows for late season weed emergence.

5. Potatoes are planted with a large hill in which the top of the hill can safely be removed with cultivation tools at about 3 weeks after planting, without damaging the developing potato shoots. This type of cultivation is referred to as "blind cultivation." This is because a grower can see the rows where the seed was placed, but no above-ground potato growth is visible. Growers closely monitor weed seed germination and potato shoot development to correctly time this cultivation, which destroys weed seedlings in the white thread to cotyledon stage.

6. Cultivation with tools such as a harrow (sometimes called "dragging off"), rolling cultivator, or power harrow when weeds are small (<1 inch). Precise timing of cultivation to small weeds is critical to obtain good weed control. Cultivation depth is shallow to prevent bringing new weed seed to the soil surface. Later (secondary) cultivation, with sweeps, shovels, and rolling cultivators, includes throwing soil on small weeds in the row when the crop is large enough to tolerate the treatment. Early weed control in the crop row reduces crop yield loss and prevents the production of further weed seeds. Cultivation at night prevents germination of some small-seeded annual weeds. Growers continue cultivation until the potato canopy becomes too large to cultivate without causing excessive damage from tires and the cultivator. Growers try to time the last cultivation as close as possible to row closure. Although late cultivation can cause significant yield loss due to root pruning, cultivation too soon before row closure brings weed seeds to the soil surface, which still has a high light penetration, and allows weeds to establish. Some of these weeds will be able to survive under the crop canopy until crop senescence, at which time they begin to regrow and quickly set seed in the shortening days of late summer and fall.

   Growers can manage most of the annual weeds found in organic potato fields with tillage and cultivation. Perennial weeds, including Canada thistle, field bindweed, purple and yellow nutsedge, and quackgrass can regrow after several cultivations, and special attention is needed to manage these weeds. Some perennial weeds are a particular problem, because if the roots are injured or cut, the cut pieces may produce new plants. Growers in eastern Washington have had good results eliminating Canada thistle in potatoes by using cultivation and fallow techniques. They cultivate fields (postharvest) to bring weed rhizomes to the surface, and then they follow with a dry summer fallow (in which nothing is left on the field). Cover crops are used during the fall, winter, and spring.

7. Irrigation management. Growers withhold irrigation water soon after cultivation to kill small weeds. When the crop is well rooted and larger than weeds, growers allow the soil surface to dry out to kill small weeds or prevent weed seeds from germinating. Drip irrigation can prevent weeds from germinating by placing water only where the crop needs it. Buried drip tubing can prevent moisture on the soil surface, thereby preventing weed germination. However, buried drip is not very compatible with potato production due to the frequent cultivations and other soil-disturbing practices that damage the buried drip lines.

8. Hand weeding those weeds that were not removed by cultivation or other methods prevents competition with the crop, and prevents weeds from forming seed and adding to the seed bank. If needed, this is the primary weed control of weed escapes after canopy closure. Growers use this technique for all weeds. It is imperative in keeping the weed seed bank low, because it removes weeds before they produce seeds. It can be a costly investment for growers, but it does eventually deplete the weed seed bank, leading to lower weeding costs in the future.

9. Fertilization management, including appropriate fertilizer levels, application timing, and placement, helps growers manage weeds. Growers add fertilizer at a level that will supply enough to the crop to out-compete the weeds but not so much that the weeds benefit. Some growers direct fertilizer applications in bands to concentrate nutrients into the crop root zone rather than doing broadcast applications, in which weeds may draw on the nutrients before the crop roots manage to make it into the inter-row zone. High nitrogen can trigger higher germination rates for some weed species (e.g., nightshade). Making a broadcast application in the prior season (e.g., in the alfalfa crop that precedes potatoes) may reduce nutrient spikes that could trigger weed germination. Most organic amendments (cow manure, compost) release nitrogen slowly, and with these, applying too much nitrogen is seldom a problem. The exception might be chicken manure, which releases nitrogen more rapidly than most organic fertilizers. With a greater number of "processed" (e.g., pelletized) chicken manure fertilizers and liquid fertilizers coming onto the market, side dressing or in-row-based fertilizer applications are much easier to undertake. Utilizing fertilizers suitable for drip systems, for example, would be one way to avoid nutrient application to the inter-row zone in order to provide an advantage to the crop over the weeds.

10. Sanitation of equipment and prevention of new weed seed introduction by composting cow manure (chicken manure is fairly weed-free), buying certified seed, keeping field edges weed-free or planting with desirable species, and washing field equipment that is contaminated with weed seed. If practical, growers also screen irrigation water to remove weed seeds.

11. Vine beaters used for vine-kill can at the same time be used to remove late season weeds and prevent them from continuing to grow and produce seed. Vine beaters kill the potato vines without disturbing the soil, which helps with potato skin set. (Vine-kill is discussed in more detail in the disease section.) This is another valuable tool for

growers to prevent weeds from seeding. Growers sometimes use a second pass over the rows to catch weed regrowth after vine beating.

12. Avoidance of fields with a known history of weed problems. In some cases, growers choose not to plant in a particular field because of the presence of difficult weed problems.

13. At harvest, growers utilize certain practices to reduce volunteer potatoes, such as the use of smaller chains on harvesters. Growers also avoid burying, with tillage or plowing, tubers left in the field after harvest, because if these are buried the volunteers are more likely to survive overwintering.

14. Management techniques not widely used by organic potato growers in the West.

    Use of biological control for weeds in potatoes is very limited. This is often due to costs, low effectiveness, and the amount of time needed for biological control to take effect. For instance, there are natural enemies that come in too late in the season to be effective at controlling the weed. Or the active life cycle of the weed and natural enemy do not coincide. For example, larvae in the genus *Bactra* are natural enemies of purple nutsedge (*Cyperus kyllingia* and *C. scirpus*); however, they do not cause appreciable damage to host plants because of their delayed seasonal buildup. The numbers of larvae remain low until early August, and buildup is necessary in late May and early June in order to properly manage nutsedge.

    The gall-forming mite, *Aceria malherbae,* was released at several sites near Prosser, Washington about 10 years ago and is established at the Irrigated Agriculture Research and Extension Center in Prosser. It is specifically a pest of the perennial field bindweed. Research has targeted its use in perennial crops such as mint, tree fruit, and grapes, since there is less tillage and soil disturbance in those crops. Less soil disturbance encourages the establishment of *A. malherbae*. The mite causes some malformed growth of the bindweed and makes it less competitive, but it is not very effective on its own and is slow to disseminate once it is released.

    Flaming can be used for weed control, but few organic potato growers use this method. Early-season weeds can be destroyed by flaming immediately prior to, or shortly after, potato emergence. Minor damage to emerging potato plants will not negatively impact tuber production. This method is expensive and causes air quality problems. Growers in Colorado do flame after vine-kill to manage weeds.

    Bed planting is used by a few growers in Colorado and Washington, especially for specialty varieties, to provide a much earlier canopy cover. A specialized planter is required. Quick canopy cover over the ground provides shading, which delays weed germination and slows weed growth. Potatoes are uniformly spaced in an offset, equidistant grid. Canopy closure is 10 to 20 days earlier in beds than in traditionally-planted hills, which greatly reduces weed pressure. Growers avoid bed planting in heavy soils, since this can cause poor drainage and resulting pathogen pressure.

Organic Herbicides. Weeds under the canopy in summer are able to quickly produce seed between vine-kill and harvest. Organic herbicides might be helpful with late-season weed control, although control of larger weeds is difficult. According to NOP standards, growers can use herbicides derived from natural sources (provided they are properly registered and labeled), but their use should be explained in the farm's Organic System Plan (an organic farm plan required for organic certification). Growers must explain that the use of cultural practices—preventive, mechanical, and physical methods—are insufficient and that the use of an organically-approved herbicide is therefore required.

The following herbicides are found on the Organic Materials Review Institute (OMRI) Products List, which is a directory of products suitable for use in certified organic production. They are all foliar, contact, and nonselective. They only control actively-growing, emerged, green vegetation. The degree of control is less when the plants are inactive, mature, or biennial/perennial types. Organic herbicides are usually cost-prohibitive, and they are largely ineffective on grass weeds, often changing the weed composition of treated areas to almost entirely grass weeds.

These herbicides can currently be used on organic potatoes:

> Weed Zap (cinnamon oil and clove oil). Weed Zap is a product that is exempt from federal registration (a FIFRA 25[b] product) and has potential to be used on crops. The product is new, and weed control is dependent upon environmental conditions. Therefore, organic potato growers are not commonly using it. Both active ingredients, cinnamon oil and clove oil, are exempt from tolerances. However, the label does not list sites to which it can be applied.
>
> Matran EC (clove oil). This product can be used in and around all crop areas. Matran EC is exempt from federal registration (a FIFRA 25[b] product). The active ingredient, clove oil, is exempt from tolerances. This product is also new, and weed control is dependent upon environmental conditions. Therefore, organic potato growers are not commonly using it.

Acetic acid and vinegar are commonly discussed as potential herbicides in organic crop production. EPA defines vinegar as being 8% or less acetic acid. Anything with greater than 8% acetic acid is referred to as acetic acid.
Acetic acid and vinegar are not currently allowed as active ingredients for herbicide use on crops under NOP standards. Acetic acid is not allowed because it is synthetic. Even though vinegar is a nonsynthetic product, it is not on the FIFRA 25(b) list (minimum risk pesticides), nor is it registered as a pesticide by EPA. Therefore NOP prohibits its use.

Weed mats or plastic mulches may be worth considering for high value crops. Weed mats are commonly installed in tree and shrub windbreaks. The mat can be installed with a small tractor. At potato planting it would be necessary to cut slits in the mat and hand plant. Removal of the mat at harvest is an issue. The mat could be rolled up at vine-kill, or a biodegradable material could be used. “Paper mats” that are used in melon crops have the potential for use in potatoes. These mats do not have to be rolled up. There is also some research into plastic mulches in organic potato production.

Weed seed predation by beetles may provide some control. The presence of weed seed-eating beetles is encouraged by planting permanent strips of vegetative cover as habitat for the beetles (known as beetle banks). Researchers at Oregon State University are studying beetle banks for weed control in organic systems (www.beetlebank.org). Growers have begun to use this practice in potatoes in the Columbia Basin. They are also currently evaluating the weed control potential of manipulating crop rotations and the tillage sequence within a rotation in order to maximize seed predation opportunities. The seed predators being studied are carabid beetles, including *Harpalus* spp., *Pterostichus melanarius*, and others. Part of the research is trying to determine how many weed seeds are actually consumed, as opposed to just being cached at another site. Many seeds are lost from established seed stations, but their fate cannot always be determined. In controlled environments, carabids are significant consumers of seeds. However, in agricultural systems, many weed seeds are buried and are not available to surface-scavenging beetles. The potential drawback to the use of beetle banks in organic systems is that these areas often become a reservoir of perennial weeds and weed seeds. For this reason, particular care during the establishment phase of the beetle bank is critical. An established grass will be much less susceptible to weed invasion. Even weeds such as bindweed can establish in grass swards and begin producing shoots outside of the beetle bank. Curly dock is notorious in grass or pasture. Perennial weeds happen everywhere disturbance is reduced.

Weeds Found in Organic Potato Fields

Annual Grasses	**Summer Annual Broadleaf Weeds**	**Winter Annual Broadleaf Weeds**	**Perennial/Biennial Weeds**
barnyardgrass *(Echinochloa crus-galli*) (summer annual)	black nightshade (*Solanum nigrum)*	birdsrape mustard (*Brassica rapa*)	Canada thistle (*Cirsium arvense*)
cheatgrass or downy brome (*Bromus tectorum*) (winter annual)	common lambsquarters (*Chenopodium album*)	black mustard (*Brassica nigra)*	dandelion (*Taraxacum officinale*)
green foxtail *(Setaria viridis)* (summer annual)	common purslane (*Portulaca oleracea*)	blue mustard (*Chorispora tenella*)	field bindweed (*Convolvulus arvensis*)
large crabgrass (*Digitaria sanguinalis*) (summer annual)	cutleaf nightshade (*Solanum triflorum)*	chickweed (*Stellaria media*)	purple nutsedge (*Cyperus rotundus*)

proso millet (*Panicum miliaceum*) (summer annual)	common cocklebur (*Xanthium pennsylvanicum*)	coast fiddleneck (*Amsinckia intermedia*)	quackgrass (*Elytrigia repens*)
yellow foxtail (*Setaria glauca*) (summer annual)	hairy nightshade (*Solanum sarrachoides*)	common groundsel (*Senecio vulgaris*)	volunteer potatoes (*Solanum tuberosum*)
wild oat (*Avena fatua*) (winter annual)	kochia (*Kochia scoparia*)	common mallow (*Malva neglecta*)	western salsify (*Tragopogon dubius*)
witchgrass (*Panicum capillare*) (summer annual)	Powell amaranth (*Amaranthus powellii*)	field mustard (*Brassica campestris*)	yellow nutsedge (*Cyperus esculentus*)
	puncturevine (*Tribulus terrestris*)	flixweed (*Descurainia Sophia*)	
	redroot pigweed (*Amaranthus retroflexus*)	henbit (*Lamium amplexicaule*)	
	Russian thistle (*Salsola iberica*)	horseweed (*Conyza canadensis)*	
	shepherd's purse (*Capsella bursa-pastoris*)	jagged chickweed (*Holosteum umbellatum*)	
	smartweed (*Polygonum lapathifolium*)	London rocket (*Sisymbrium irio*)	
	sowthistle, annual (*Sonchus oleraceus*)	Oriental mustard (*Sisymbrium orientale*)	
		prickly lettuce (*Lactuca serriola*)	
		redstem filaree (*Erodium cicutarium*)	
		spiny sowthistle (*Sonchus asper*)	
		tall hedge mustard (*Sisymbrium loeselii* L.)	
		tansy mustard (*Descurainia pinnata*)	
		tumble mustard (*Sisymbrium altissimum*)	
		wild radish (*Raphanus raphanistrum*)	

Critical Needs for Management of Weeds in Organic Potatoes in the Western U.S.

Research

- Research the control of perennial weeds (especially Canada thistle and field bindweed), including the use of deep mechanical removal, when it is not possible to rotate with alfalfa.
- Test the residue management theory (plant into high biomass, no-till, rolled cover crops) for weed management.
- Research the use of beneficial gall-forming mites for weed management. (Their feeding deforms leaves.)
- Research the use of acetic acid, including its efficacy (especially on perennial weeds) and optimal and safe use rates.
- Research rotational partners (including green manures) and their benefits or potential harm to weed management in organic potatoes.
- Research biofumigants to determine which ones help with weed management.
- Research the use of weed mats in planting beds to control weeds.
- Research the effects of altering bed shapes for weed management, including how water runoff from steeper hills affects weeds.
- Research the influence of night cultivation on weed seed germination.
- Research weeds as hosts to diseases and insects.
- Research yellow and purple nutsedge biology and cultural controls. (Yellow nutsedge is becoming a weed problem in the Columbia Basin and is a weed problem in California and Colorado. Purple nutsedge is a problem in California.).
- Research efficacy of OMRI-listed potential vine-kill products for managing weeds, such as Green Match (limonene), Blackberry and Brush Block (citric acid).
- Research beetles and beetle banks and their effectiveness on weed seed predation in organic potatoes.
- Research a method to control weeds after vine-kill.
- Research effectiveness of *Brassica* seed meals on weed control in organic potatoes.
- Dedicate university or farmers' land for organic potato production research, to be managed organically for the long term.

Regulatory

- Facilitate the registration of acetic acid products for organic potato production.
- Facilitate the approval of synthetic herbicides such as pelargonic acid in organic production.
- Facilitate getting tolerances, or exemptions from tolerances, for plant-derived active ingredients that are already registered for noncrop uses for use in organic potatoes after vine-kill.

- Address state rules on seed potato production areas so that growing organic potato seed is allowed as long as it does not jeopardize conventional seed production. Organic seed may have to be grown in isolated areas away from Potato Seed Management Areas.
- Encourage USDA to provide additional funding for organic research.

Education

- Educate growers about existing biocontrols and about habitat modifications that can be made in order to increase weed seed predators.
- Educate growers about the importance of scouting and weed identification.
- Disseminate information about weed mat research to growers.
- Educate growers about weed life cycles so they know when it is best to manage them.
- Educate growers about the impact of mechanical weed control on potato plant health and yield.
- Educate organic growers about organic research being done by university researchers.
- Educate growers, extension personnel, and other industry personnel about regulatory issues (e.g., NOP standards and seed certification).
- Educate extension personnel about how best to distribute information to organic potato growers.
- Provide accessible, Web-based pest management information for organic potatoes, including an online clearinghouse for research data (potentially an eXtension Web site for organic potato growers).
- Educate university researchers about the need for dedicated organic research land.
- Create a regional organic work group for research activities (e.g., through the Western IPM Center).
- Educate growers and agriculture professionals about how to convey organic farming issues to legislators (i.e., lobbying).

Vertebrates

Voles and mice can be a major problem in organic potato production in the West. The California pocket gopher is also a problem in organic potato growing regions in California, Colorado, and some other areas.

Growers struggle with how to manage these pests. They harvest the potatoes as soon as possible and provide habitat and nest boxes for raptors and owls to encourage predation. Some growers also use traps.

If these methods do not provide effective control, some growers use Vitamin D_3 (Cholecalciferol) or sulfur dioxide (smoke bombs). Rodents generally die of hypercalcemia within two days of ingesting Vitamin D_3. Growers take care when placing the Vitamin D_3 pellets, since dogs and young male cats are also attracted to the bait. A few organic farmers add sulfur flakes (100% sulfur) to a tunnel, light it, and then seal the tunnel. Burning sulfur (flaked sulfur) releases sulfur dioxide (SO_2) when it is ignited. Sulfur "smoke sticks" have also been used on organic farms to control pocket gophers. NOP compliance can be an issue with these products because of their inert ingredients. Poison gases are not effective for controlling moles that have extensive tunnel systems, because the moles quickly plug and seal off the gassed section.

Critical Needs for Management of Vertebrates in Organic Potatoes in the Western United States

Research
- Research how to control vertebrate pests in organic potato systems.
- Research the use and efficacy of repellents to deter vertebrates.

Regulatory
- Make sure that the researched solutions get registered and receive NOP approval.
- Encourage USDA to provide additional funding for organic research.

Education
- Educate organic growers on vertebrate control methods.
- Educate researchers about the need for more research on vertebrate pest management in organic potato systems.
- Educate organic growers about organic research being done by university researchers.
- Educate extension personnel about how best to distribute information to organic potato growers.
- Provide accessible, Web-based pest management information for organic potatoes, including an online clearinghouse for research data (potentially an eXtension Web site for organic potato growers).
- Educate university researchers about the need for dedicated organic research land.

- Create a regional organic work group for research activities (e.g., through the Western IPM Center).
- Educate growers and agriculture professionals about how to convey organic farming issues to legislators (i.e., lobbying).

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Appendix 1:
Organic Potato Production Regulatory Information

Background on the Organic Foods Production Act
Congress passed the Organic Foods Production Act (OFPA) of 1990 as part of the 1990 Farm Bill. The OFPA required the U.S. Department of Agriculture (USDA) to develop national standards for organically produced agricultural products to ensure that organically labeled products meet consistent, uniform standards. The OFPA and the National Organic Program (NOP) regulations require that agricultural products labeled as organic originate from farms or handling operations certified by a state or private entity that has been accredited by USDA.

Full implementation of the national organic standards went into effect October 21, 2002. The NOP developed national organic standards and established an organic certification program based on recommendations of the National Organic Standards Board (NOSB). Board members are appointed by the Secretary of Agriculture and include representatives from the following categories: farmer/grower, handler/processor, retailer, consumer/public interest, environmentalist, scientist and certifying agent. Recommendations made by the NOSB are not official policy until they are approved by the USDA NOP.

The NOP standards govern production, handling, labeling and certification of organic products, as well as accreditation standards for certifying agencies.

The Use of Pesticides in Organic Production
The NOP emphasizes the use of preventive and cultural methods such as crop rotation, biological controls, selection of resistant varieties, and sanitation measures to prevent pest problems and maintain crop health. Growers can use certain pesticides in organic production, provided they are registered and labeled in the grower's state, but their use must be explained in the Organic System Plan (hereafter called the "Plan"). In the Plan, growers explain that the use of cultural practices—preventive, mechanical, and physical methods, for example—are insufficient, thus requiring the use of an organically-approved pesticide.

There are certain criteria that a pesticide must meet in order to be approved for use on certified organic cropland. These criteria are

I. ***Organically-approved ingredients:*** Both the active and inert ingredients must be approved for organic production by the National Organic Program (NOP).
II. ***Registered or exempted ingredients:*** The active and inert ingredients must be either registered by the Environmental Protection Agency (EPA) or exempted from registration by EPA.
III. ***Established Tolerances:*** The active ingredients and inert ingredients must have an established tolerance for the crop, or must be exempt from the requirement of a tolerance.

IV. ***State Registration:*** The product must also be registered by the state for the desired crop. (Some states do not require exempted products to be registered with the state. More details below.)

I. Organically-Approved Ingredients

The NOP is the only entity that manages the National List of Allowed and Prohibited Substances (National List). The NOP regulation requires that pesticides have active ingredients that are either considered natural or are synthetic and appear on the National List (7CFR 205.600-607). Generally, most synthetic substances are prohibited unless they appear on the National List as allowed. Most natural substances (i.e., nonsynthetic) are allowed unless they appear on the National List as prohibited.

Inert ingredients in pesticides are those ingredients that are not intended to affect a target pest but are added to enhance some characteristic of the pesticide. Inert ingredients of pesticide products are not necessarily harmless, and some may be quite toxic. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), which governs pesticide registration, does not require inert ingredients to be identified by name on the product label. However, the total percentage of inert ingredients must be declared, and many pesticide products contain a larger percentage of inert ingredients than active ingredients. The EPA classifies inert ingredients in four lists:

- List 1 (Inert Ingredients of Toxicological Concern)
- List 2 (Potentially Toxic Other Ingredients/High Priority for Testing Inerts)
- List 3 (Inert Ingredients of Unknown Toxicity)
- List 4A (Inert Ingredients of Minimal Concern)
- List 4B (Other ingredients for which EPA has sufficient information to reasonably conclude that the current use pattern in pesticide products will not adversely affect public health or the environment.)

In organically-approved products, all inert ingredients must be classified as List 4 (4A or 4B) as of August 2004. List 3 inert ingredients may be permitted if they are individually reviewed and added to the NOP's National List, or are used in passive pheromone dispensers.

The National List is a generic materials list. It only specifies the allowed synthetic substances and prohibited nonsynthetic materials (see sections 205.601 and 205.602). The National List does not list all of the natural (nonsynthetic) substances that are allowed by definition. The NOP does not publish a brand name materials list.

The Organic Materials Review Institute (OMRI) reviews products to determine their suitability for use in producing, processing, and handling of organic food and fiber under the USDA NOP rule. OMRI listed—or approved—products may be used on operations that are certified organic under the NOP. OMRI maintains a directory of all the materials allowed and prohibited in organic production and handling (*OMRI Generic Materials List*), as well as a directory of commercially named products that are suitable for use in certified organic production (*OMRI Products List*). This information can be found at the OMRI Web site, and additional information is available through a subscription to OMRI at http://www.omri.org/.

OMRI is not the sole reviewer of approved materials. The Washington State Department of Agriculture (WSDA) maintains a list of approved products, and the California Certified Organic Farmers (CCOF) reviews products that are not on the OMRI or WSDA lists when that is requested by growers. Manufacturers can register with the EPA to affix the EPA's "For Organic Production" logo on acceptable product labels. Or they can make a statement on the product saying that it complies with the USDA-NOP requirements and therefore does not have to go through OMRI or WSDA.

Under the NOP regulation, it is the growers' responsibility to determine what is approved for organic use. Growers should always check with their certification agency to determine the acceptability of a pesticide or other input prior to purchasing or applying the substance.

II. *Registered and Exempted Ingredients*
Pesticide registration is governed by FIFRA and regulated at the federal level by EPA. Any product making a pesticidal claim must be registered with EPA and is assigned an EPA registration number, which is located on the product label.

Pesticides containing active ingredients found on the EPA's Minimum Risk Pesticides list, or 25(b) list, are exempt from the requirements of a federal registration. These products will not have an EPA registration number. Products containing these active ingredients must adhere to the following criteria in order to be exempted from the normal requirements of federal registration:

- Each product must have a label identifying the name and percentage (by weight) of each active ingredient and the name of each inert ingredient. Inert ingredients must be found on EPA's 4A list in order to be exempt from federal registration.
- The product cannot make claims to control or mitigate microorganisms that pose a threat to human health, including but not limited to, disease-transmitting bacteria or viruses, or make claims to control insects or rodents carrying specific diseases, including but not limited to, ticks that carry Lyme disease.
- The product must not include any false or misleading labeling statements. Section 2(q)(1)(A) of FIFRA lists ten false or misleading statements. Pesticide products registered with EPA cannot have any of these claims on their labels. Pesticide products whose active ingredients are found on the 25(b) list, however, only have to adhere to the first eight statements.
- Some states require state pesticide registration of these products before the products can be approved for sale, distribution and use in that state.

A listing on EPA's 25(b) list does not automatically qualify a pesticide active ingredient for use in organic production. In order to determine whether or not a pesticide product is suitable for organic production, a grower must check with the organic certifying agency in his or her state, or check the Generic Materials List or Product List maintained by OMRI or other organizations. Some exempt products—but not all—meet the requirements of the USDA National Organic Program. For example, a product that has active ingredients found on the 25(b) list but that is formulated with inert ingredients not allowed by NOP would not be organically-approved.

III. *Established Tolerances*

In addition to being organically-approved, all active and inert ingredients must have a residue tolerance, or an exemption from tolerance, established for any food or animal feed crop that is listed on the label. Tolerances are the maximum legally-permissible levels of pesticide residues, including active and inert ingredients, that may be found in foods. Not all pesticides that are exempt from a federal registration (i.e., those found on the 25[b] list) are exempt from the requirement of a tolerance.

The pesticide product label may bear only those food uses for which there are tolerances, or exemptions from tolerances, for the active and inert ingredients. If the tolerance exemption is for all food commodities, then any food crops, food surfaces or animal feed crops can be listed on the label. Active and inert ingredients can be exempted from the requirement of a tolerance if they are considered safe enough for use at any level.

Established tolerances and tolerance exemptions can be found in 40 CFR Part 180, entitled *Tolerances and Exemptions from Tolerances for Pesticide Chemicals Found in Food*. http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=0b38e2b637052c05d2c2a4c36e6583e5&tpl=/ecfrbrowse/Title40/40cfr180_main_02.tpl. If residue testing of a crop detects prohibited substances at levels greater than 5% of the EPA tolerance for the specific residue detected or unavoidable residual environmental contamination, the crop may not be sold, labeled, or represented as organically produced. Potatoes are known to accumulate persistent soilborne pesticides. They may be contaminated by pesticides prohibited in organic production but that have not been applied to a field in more than three years.

IV. *State Registration*

Even if a pesticide product qualifies for exemption from federal registration under 25(b), the product may not be exempt from state registration or other regulatory requirements. Each state has its own statutes and regulations concerning pesticide registration and regulation of 25(b) products. However, even states that do not require registration do retain oversight of the products. Products found in the marketplace must adhere to state and federal regulatory standards.

Below is a summary of the registration requirements for 25(b) products among Western states:

> *California:* The California Department of Pesticide Regulation (CDPR) does not require registration of these products. Companies selling 25(b) products are not required to submit labels to CDPR prior to sale of the products. CDPR maintains a database with all pesticide products registered in California at http://www.cdpr.ca.gov/docs/label/labelque.htm.

Colorado: The Colorado Department of Agriculture (CDA) requires the 25(b) products to be registered. Growers can check their web page to determine if a product is registered for the current year: http://www.colorado.gov/cs/Satellite/Agriculture-Main/CDAG/1167928162834.

Idaho: The Idaho State Department of Agriculture (ISDA) does not require registration of the 25(b) products. Manufacturers are required to submit product labels to ISDA, and ISDA checks the labels to make sure required label elements are present. ISDA tracks pesticide registrations on their site using the Kelly Solutions database, http://www.kellysolutions.com/ID/.

Oregon: The Oregon Department of Agriculture (ODA) does not require registration of the 25(b) products. Manufacturers are required to submit a copy of the label to ODA, and ODA checks the labels to make sure required label elements are present. The Pesticide Information Center Online (PICOL) is a searchable database that enables users to find information on pesticides registered in Oregon and Washington: http://picol.cahe.wsu.edu/LabelTolerance.html.

Washington: The Washington State Department of Agriculture (WSDA) requires the 25(b) products to be registered. They are treated the same as products registered at the federal level. The Pesticide Information Center Online (PICOL) is a searchable database that enables users to find information on pesticides registered in Oregon and Washington: http://picol.cahe.wsu.edu/LabelTolerance.html.

Issues of Concern

Efficacy

It is important to know that the efficacy of any pesticide product, whether it is organically approved or not, is never guaranteed. Federal registration of a pesticide product requires the submission of an extensive data packet that includes data to demonstrate efficacy. However, EPA registration decisions are not based on efficacy (except for disinfectants used for human health). Since it is not required that pesticide active ingredients on EPA's 25(b) list be federally registered, efficacy studies for these active ingredients may or may not have been performed. A pesticide may be OMRI-approved and may be registered (at the federal or state level, or both), but none of this would guarantee the product's efficacy.

Burden of Proof on the Producer

It is the responsibility of organic growers to use only inputs that are approved for organic use. Prior to purchasing or applying the substance, growers should always check with their certification agency to determine the acceptability of a pesticide or other input. All inputs used must be included in the Organic System Plan and be approved by the certification agency prior to use.

Activity Tables for Organic Potatoes in California

Field Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Bed prep			X			X	X				X	
Planting and drag-off	X	X	X	X	X	X	X	X	X		X	X
Organic fertilizer application	X	X	X	X	X	X	X				X	X
Hilling/blind cultivation		X	X			X	X					
Cultivation			X	X	X	X			X	X		X
Irrigation	X	X	X	X	X	X	X	X	X	X	X	
Vine-kill			X	X	X	X	X	X	X	X	X	
Harvest	X			X	X	X	X	X	X	X	X	X
Storage	X	X	X	X		X	X	X	X	X	X	X

Note: Information based on grower experience.

Cultural Pest Management Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Aerial monitoring												
Avoiding contaminated water for irrigation	X	X	X	X	X	X	X	X	X	X	X	X
Avoiding planting in fields with high pest densities			X	X	X	X	X	X			X	
Avoiding skips	X	X			X	X	X					X
Barriers												
Bed planting	X	X			X	X	X					X
Bug vacuum						X	X	X				
Compost source		X	X			X	X				X	X
Controlling volunteer potatoes	X	X	X	X	X							
Crop rotation	X			X	X	X	X	X	X	X	X	X
Cull pile management	X	X	X			X	X			X	X	X
Cultivation			X	X	X	X			X	X		X
Early harvest	X	X	X		X	X				X		X
Early maturing varieties		X	X									
Eliminating host plants		X	X				X	X		X	X	X
Eliminating weedy host plants	X	X	X	X			X	X	X	X	X	X
Equipment sanitation	X	X	X	X	X	X					X	X
Farmscaping (beneficial planting across farm)	X											
Fallowing	X			X	X	X	X	X	X	X	X	X
Fertilizer management	X	X	X	X	X			X	X	X	X	X
Field location and selection	X	X	X	X	X	X	X	X	X			
Flaming												
Flooding												
Grazing												
Hand weeding	X	X	X	X	X	X	X	X	X	X	X	X
Hand removal of pests												

Cultural Pest Management Activities (continued)												
Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Harvest techniques									X	X		
High hilling			X	X	X	X	X	X	X		X	X
High quality, certified, disease-free seed	X	X	X			X	X				X	X
Incorporating green manures	X					X	X		X	X	X	X
Insectary plantings	X											
Minimizing leaf wetness	X	X	X	X	X	X	X	X	X	X	X	X
Monitoring canopy moisture, temperature and humidity												
Monitoring soil moisture	X	X	X	X	X	X	X	X	X	X	X	X
Monitoring soil temperature	X	X	X	X	X	X		X	X		X	X
Monitoring temperature and humidity (storage)	X	X	X	X		X	X	X	X	X	X	X
Mowing			X	X	X	X			X	X		
Mulch												
pH management		X	X	X		X	X		X	X	X	
Planting clean seed	X	X	X	X	X	X					X	X
Planting cover crops/ green manures	X	X	X					X	X	X	X	X
Plant spacing	X	X	X	X	X	X		X			X	X
Planting date alteration	X	X	X	X	X	X					X	X
Planting depth	X	X	X	X	X	X		X			X	X
Proper seed cutting	X	X	X	X	X	X		X			X	X
Proper soil drainage			X	X	X	X	X	X	X	X	X	X
Proper storage	X	X	X	X						X	X	X
Rapid canopy closure	X	X	X	X	X	X	X	X	X		X	X
Resistant varieties	X	X	X			X	X		X	X		
Rolling vines and covering with soil			X	X	X	X	X	X	X		X	
Sanitation	X	X	X	X	X	X	X	X			X	X
Sealing soil cracks			X	X	X	X	X	X	X		X	X
Trap crops												
Trapping for monitoring												
Variety selection	X	X			X	X	X	X	X	X		

Note: Information based on grower experience.

Organic Pesticide Treatment Activities

If an organic pesticide product is sometimes applied, X indicates which month that application occurs for each pest. A blank space indicates that no activity is performed for this pest. The pest still occurs and may be a problem, but activities or treatments are not done because of lack of products or the results from activities may not be efficacious or economically feasible.

Nematodes	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root-knot nematode			X	X	X	X	X					
Root-lesion nematode			X	X	X	X	X					
Stubby-root nematode			X	X	X	X	X					
Insects	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Colorado potato beetles												
False chinch bug												
Flea beetles			X	X	X	X	X	X	X	X		
Green peach aphid												
Grasshoppers			X	X	X	X	X					
Leafhoppers			X	X	X	X	X	X				
Loopers, armyworms, cutworms				X		X	X					
Potato psyllids			X	X	X	X	X	X	X	X		
Potato tuberworm			X	X	X	X		X	X			
Seedcorn maggot												
Spider mites												
Symphylans												
Wireworms												
Diseases	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bacterial ring rot												
Black dot						X	X	X				
Black leg-soft rot disease complex		X	X	X	X	X	X	X				
Calico												
Charcoal rot												
Common scab	X	X	X	X	X	X	X	X	X	X	X	X
Early blight	X	X	X	X	X	X	X	X		X	X	X
Early dying												
Fusarium dry rot	X		X	X	X	X		X			X	X
Late blight	X	X	X	X	X	X	X	X		X	X	X
Pink rot					X	X	X					
PLRV												
Powdery mildew												
Powdery scab												
Purple-top mycoplasma												
PVA												
PVX												
PVY												
Pythium leak	X	X	X	X	X	X	X	X	X	X	X	X
Rhizoctonia/black scurf	X	X	X	X	X	X	X	X			X	X
Silver scurf	X	X	X	X	X	X	X	X	X		X	X

Organic Pesticide Treatment Activities (continued)

If an organic pesticide product is sometimes applied, X indicates which month that application occurs for each pest. A blank space indicates that no activity is performed for this pest. The pest still occurs and may be a problem, but activities or treatments are not done because of lack of products or the results from activities may not be efficacious or economically feasible.

Diseases (continued)	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Southern blight												
White mold	X	X	X	X	X	X				X	X	X
Weeds	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Annual grass weeds												
Summer annual broadleaf weeds												
Winter annual broadleaf weeds												
Perennial/biennial weeds												
Canada thistle												
Field bindweed												
Nightshade (Hairy, Cutleaf, Black)												
Nutsedge (Yellow, Purple)												
Quackgrass												
Vertebrate Pests	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
California pocket gopher												
Voles and mice												

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

Activity Tables for Organic Potatoes in Colorado

Field Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Bed prep				X								
Planting and drag-off					X							
Organic fertilizer app.		X		X	X	X	X	X		X	X	
Hilling/blind cultivation				X	X	X						
Cultivation					X	X	X					
Irrigation					X	X	X	X	X			
Vine-kill							X	X	X			
Harvest							X	X	X	X		
Storage	X	X	X	X	X				X	X	X	X

Note: Information based on grower experience.

Cultural Pest Management Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Aerial monitoring						X	X	X				
Avoiding contaminated water for irrigation				X	X	X	X	X	X			
Avoiding planting in fields with high pest densities	X	X	X							X	X	
Avoiding skips				X								
Barriers				X								
Bed planting					X							
Bug vacuum												
Compost source	X	X		X						X	X	X
Control volunteer potatoes											X	
Crop rotation	X			X								
Cull pile management	X	X	X	X		X	X	X	X	X	X	X
Cultivation					X	X	X					
Early harvest							X	X				
Early maturing varieties	X						X	X				
Eliminating host plants	X				X	X						
Eliminating weedy host plants	X				X	X	X					
Equipment sanitation			X	X	X	X	X	X	X	X		
Farmscaping (beneficial planting across farm)												
Fallowing	X			X								
Fertilizer management	X		X	X	X	X	X					
Field location & selection	X									X	X	X
Flaming								X	X	X		
Flooding												
Grazing	X			X							X	
Hand weeding	X				X	X	X					

Cultural Pest Management Activities (continued)

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Hand removal of pests							X	X				
Harvest techniques							X	X	X	X		
High hilling				X	X	X	X					
High quality, certified seed		X	X	X	X	X						
Incorporate green manures								X	X			
Insectary plantings									X			
Minimizing leaf wetness							X	X	X			
Monitoring canopy moisture, temperature, and humidity					X	X	X	X				
Monitoring soil moisture			X	X	X	X	X	X	X			
Monitoring soil temperature	X	X	X	X	X				X	X	X	X
Monitoring temperature and humidity (storage)	X	X	X	X	X				X	X	X	X
Mowing						X	X	X	X			
Mulch										X	X	
pH management		X	X								X	X
Planting clean seed			X	X	X							
Planting cover crops/green manures						X			X	X		
Plant spacing			X	X	X							
Planting date alteration			X	X	X							
Planting depth			X	X	X							
Proper seed cutting			X	X	X							
Proper soil drainage				X	X	X	X	X	X			
Proper storage	X	X	X	X	X					X	X	X
Rapid canopy closure						X	X	X				
Resistant varieties					X							
Rolling vines and covering with soil								X	X			
Sanitation	X	X	X	X	X	X	X	X	X	X	X	X
Sealing soil cracks								X	X			
Trap crops						X	X					
Trapping for monitoring					X	X	X					
Variety selection	X	X								X	X	X

Note: Information based on grower experience.

Organic Pesticide Treatment Activities												
If an organic pesticide product is sometimes applied, X indicates which month that application occurs for each pest. A blank space indicates that no activity is performed for this pest. The pest still occurs and may be a problem, but activities or treatments are not done because of lack of products or the results from activities may not be efficacious or economically feasible.												
Nematodes	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root-knot nematode			X	X	X							
Root-lesion nematode			X	X	X							
Stubby-root nematode			X	X	X							
Insects												
Colorado potato beetles												
False chinch bug												
Flea beetles						X	X					
Green peach aphid						X	X	X				
Leafhoppers												
Loopers, armyworms, cutworms						X	X					
Potato psyllids			X	X	X	X	X	X				
Seedcorn maggot												
Spider mites												
Wireworms												
Diseases												
Bacterial ring rot												
Black dot												
Black leg-soft rot disease complex						X	X					
Calico												
Common scab												
Early blight						X	X	X				
Early dying												
Fusarium dry rot						X	X					
Late blight						X	X	X				
Pink rot												
PLRV												
Powdery mildew												
Powdery scab												
Purple-top mycoplasma												
PVA												
PVX												
PVY												
Pythium leak												
Rhizoctonia/black scurf												
Silver scurf						X	X					
Southern blight												
White mold						X	X					

Organic Pesticide Treatment Activities (continued)

If an organic pesticide product is sometimes applied, X indicates which month that application occurs for each pest. A blank space indicates that no activity is performed for this pest. The pest still occurs and may be a problem, but activities or treatments are not done because of lack of products or the results from activities may not be efficacious or economically feasible.

Weeds	J	F	M	A	M	J	J	A	S	O	N	D
Annual grass weeds												
Summer annual broadleaf weeds												
Winter annual broadleaf weeds												
Perennial/biennial weeds												
Canada thistle												
Field bindweed												
Nightshade (Hairy, Cutleaf, Black)												
Nutsedge (Yellow, Purple)												
Quackgrass												
Vertebrates												
California pocket gopher												
Voles and mice												

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

Activity Tables for Organic Potatoes in the Columbia Basin

Field Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Bed prep		X	X	X	X							
Planting and drag-off			X	X	X							
Organic fertilizer application	X	X	X	X	X		X	X	X	X	X	X
Hilling/blind cultivation			X	X	X							
Cultivation			X	X	X	X						
Irrigation			X	X	X	X	X	X	X			
Vine-kill						X	X	X	X	X		
Harvest							X	X	X	X	X	
Storage	X	X	X	X	X	X			X	X	X	X

Note: Information based on grower experience.

Cultural Pest Management Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Aerial monitoring						X	X	X				
Avoiding contaminated water for irrigation			X	X	X	X	X	X	X			
Avoiding planting in fields with high pest densities			X	X	X							
Avoiding skips			X	X	X							
Barriers	This practice is not used in this region.											
Bed planting	This practice is not used in this region.											
Bug vacuum	This practice is not used in this region.											
Compost source		X	X	X	X							
Controlling volunteer potatoes			X	X	X	X	X	X	X	X		
Crop rotation	X	X	X	X	X	X	X	X	X	X	X	X
Cull pile management	X	X	X	X	X	X	X	X	X	X	X	X
Cultivation			X	X	X	X						
Early harvest									X	X		
Early maturing varieties	This practice is not used in this region.											
Eliminating host plants					X	X	X	X				
Eliminating weedy host plants				X	X	X	X	X	X			
Equipment sanitation		X	X	X	X	X	X	X	X	X		
Farmscaping (beneficial planting across farm)	X	X	X	X	X	X	X	X	X	X	X	X
Fallowing	X	X	X	X	X	X	X	X	X	X	X	X
Fertilizer management	X	X	X	X	X	X	X	X	X	X	X	X
Field location and selection		X	X	X	X	X						
Flaming	This practice is not used in this region.											
Flooding	This practice is not used in this region.											
Grazing	This practice is not used in this region.											
Hand weeding	This practice is not used in this region.											
Hand removal of pests	This practice is not used in this region.											

Cultural Pest Management Activities (continued)												
Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Harvest techniques							X	X	X	X		
High hilling				X	X	X						
High quality, certified seed			X	X	X							
Incorporating green manures			X	X						X	X	
Insectary plantings				X	X	X	X	X	X			
Minimizing leaf wetness	X	X	X	X	X	X	X	X	X	X	X	X
Monitoring canopy moisture, temperature and humidity				X	X	X	X	X	X			
Monitoring soil moisture		X	X	X	X	X	X	X	X	X		
Monitoring soil temperature		X	X	X	X					X	X	
Monitoring temperature and humidity (storage)	X	X	X	X	X				X	X	X	X
Mowing					X	X	X	X	X			
Mulch	This practice is not used in this region.											
pH management	This practice is not used in this region.											
Planting clean seed			X	X	X							
Planting cover crops/ green manures								X	X	X		
Plant spacing			X	X	X							
Planting date alteration			X	X	X							
Planting depth			X	X	X							
Proper seed cutting			X	X	X							
Proper soil drainage	X	X	X	X	X				X	X	X	X
Proper storage	X	X	X	X	X					X	X	X
Rapid canopy closure				X	X	X						
Resistant varieties			X	X	X							
Rolling vines and covering with soil	This practice is not used in this region.											
Sanitation	X	X	X	X	X	X	X	X	X	X	X	X
Sealing soil cracks									X	X		
Trap crops	This practice is not used in this region.											
Trapping for monitoring	X	X	X	X	X	X	X	X	X	X	X	X
Variety selection	X	X	X	X								

Note: Information based on grower experience.

Organic Pesticide Treatment Activities

If an organic pesticide product is sometimes applied, X indicates which month that application occurs for each pest. A blank space indicates that no activity is performed for this pest. The pest still occurs and may be a problem, but activities or treatments are not done because of lack of products or the results from activities may not be efficacious or economically feasible.

Nematodes	J	F	M	A	M	J	J	A	S	O	N	D
Root-knot nematode												
Root-lesion nematode												
Stubby-root nematode												
Insects												
Colorado potato beetles						X	X	X	X			
False chinch bugs												
Flea beetles												
Green peach aphid						X	X	X	X			
Leafhoppers						X	X	X	X			
Loopers, armyworms, cutworms						X	X	X	X			
Potato psyllids						X	X	X	X			
Potato tuberworm							X	X	X	X		
Seedcorn maggot			X	X	X							
Spider mites												
Western spotted cucumber beetle larvae												
Wireworms												
Diseases												
Bacterial ring rot												
Black dot												
Black leg-soft rot disease complex												
Calico												
Early blight						X	X	X				
Early dying												
Fusarium dry rot												
Late blight						X	X	X				
Pink rot												
PLRV												
Powdery mildew												
Powdery scab												
Purple-top mycoplasma												
PVA												
PVX												
PVY												
Pythium leak												
Rhizoctonia/black scurf												
Silver scurf	X	X	X								X	X
Southern blight												
White mold						X	X	X				

Organic Pesticide Treatment Activities

If an organic pesticide product is sometimes applied, X indicates which month that application occurs for each pest. A blank space indicates that no activity is performed for this pest. The pest still occurs and may be a problem, but activities or treatments are not done because of lack of products or the results from activities may not be efficacious or economically feasible.

Weeds	J	F	M	A	M	J	J	A	S	O	N	D
Annual grass weeds												
Summer annual broadleaf weeds												
Winter annual broadleaf weeds												
Perennial/biennial weeds												
Canada thistle												
Field bindweed												
Nightshade (Hairy, Cutleaf, Black)												
Nutsedge (Yellow, Purple)												
Quackgrass												
Vertebrates												
California pocket gopher												
Voles and mice			X	X				X	X	X		

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

Activity Tables for Organic Potatoes in Idaho

Field Activities												
Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bed prep			X	X				X	X	X	X	
Planting and drag-off				X	X							
Organic fertilizer application				X	X		X		X	X	X	
Hilling/blind cultivation					X							
Cultivation					X	X						
Irrigation					X	X	X	X	X			
Vine-kill								X	X			
Harvest								X	X	X		
Storage	X	X	X	X	X				X	X	X	X

Note: Information based on grower experience.

Cultural Pest Management Activities												
Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Aerial monitoring						X	X	X	X			
Avoiding contaminated water for irrigation					X	X	X	X	X	X		
Avoiding planting in fields with high pest densities			X									
Avoiding skips				X	X							
Barriers												
Bed planting												
Bug vacuum												
Compost source									X	X	X	
Controlling volunteer potatoes			X	X								
Crop rotation												
Cull pile management			X	X	X							
Cultivation					X	X						
Early harvest								X				
Early maturing varieties								X				
Eliminating host plants			X	X	X	X	X					
Eliminating weedy host plants			X	X	X	X	X					
Equipment sanitation			X	X				X	X	X		
Farmscaping (beneficial planting across farm)												
Fallowing												
Fertilizer management			X	X	X	X	X	X			X	
Field location and selection		X	X	X				X	X	X	X	
Flaming												
Flooding												
Grazing												
Hand weeding						X	X					
Hand removal of pests												

Cultural Pest Management Activities (continued)

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Harvest techniques								X	X	X		
High hilling				X	X							
High quality, certified seed			X	X								
Incorporating green manures			X									
Insectary plantings												
Minimizing leaf wetness					X	X	X	X				
Monitoring canopy moisture, temperature, and humidity						X	X	X				
Monitoring soil moisture					X	X	X	X	X			
Monitoring soil temperature				X				X	X	X		
Monitoring temperature and humidity (storage)	X	X	X	X	X				X	X	X	X
Mowing								X	X			
Mulch												
pH management												
Planting clean seed				X	X							
Planting cover crops/green manures								X	X			
Plant spacing				X	X							
Planting date alteration				X	X							
Planting depth				X	X							
Proper seed cutting			X	X	X							
Proper soil drainage			X	X	X							
Proper storage	X	X	X						X	X	X	X
Rapid canopy closure					X	X						
Resistant varieties			X	X	X							
Rolling vines and covering with soil								X	X	X		
Sanitation			X	X	X			X	X	X		
Sealing soil cracks									X	X		
Trap crops												
Trapping for monitoring					X	X	X	X				
Variety selection			X	X								

Note: Information based on grower experience.

Organic Pesticide Treatment Activities

If an organic pesticide product is sometimes applied, X indicates which month that application occurs for each pest. A blank space indicates that no activity is performed for this pest. The pest still occurs and may be a problem, but activities or treatments are not done because of lack of products or the results from activities may not be efficacious or economically feasible.

Nematodes	J	F	M	A	M	J	J	A	S	O	N	D
Root-knot nematode								X	X			
Root-lesion nematode								X	X			
Stubby-root nematode								X	X			
Potato cyst nematode												
Insects												
Colorado potato beetles					X	X	X					
False chinch bugs												
Flea beetles												
Grasshoppers												
Green peach aphid						X	X					
Leafhoppers												
Loopers, armyworms, cutworms						X	X					
Potato psyllids												
Potato tuberworm												
Seedcorn maggot												
Spider mites												
Wireworms												
Diseases												
Bacterial ring rot												
Black dot												
Black leg-soft rot disease complex												
Common scab												
Early blight												
Early dying												
Fusarium dry rot												
Late blight												
Pink rot												
PLRV												
Powdery mildew												
Powdery scab												
Purple-top mycoplasma												
PVA												
PVX												
PVY												
Pythium leak												
Rhizoctonia/black scurf												
Silver scurf												
Southern blight												
White mold												

Organic Pesticide Treatment Activities (continued)

If an organic pesticide product is sometimes applied, X indicates which month that application occurs for each pest. A blank space indicates that no activity is performed for this pest. The pest still occurs and may be a problem, but activities or treatments are not done because of lack of products or the results from activities may not be efficacious or economically feasible.

Weeds	J	F	M	A	M	J	J	A	S	O	N	D
Annual grass weeds												
Summer annual broadleaf weeds												
Winter annual broadleaf weeds												
Perennial/biennial weeds												
Canada thistle												
Field bindweed												
Nightshade (Hairy, Cutleaf, Black)												
Nutsedge (Yellow, Purple)												
Quackgrass												
Vertebrates												
California pocket gopher												
Voles and mice												

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

Activity Tables for Organic Potatoes in Klamath Basin

Field Activities												
Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bed preparation				X	X							
Planting and drag-off				X	X	X						
Organic fertilizer application			X	X	X	X	X	X				
Hilling/blind cultivation					X	X						
Cultivation					X	X	X					
Irrigation				X	X	X	X	X	X	X		
Vine-kill							X	X	X			
Harvest								X	X	X		
Storage	X	X	X	X	X	X			X	X	X	X

Note: Information based on grower experience.

Cultural Pest Management Activities												
Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Aerial monitoring						X	X	X	X			
Avoiding contaminated water for irrigation												
Avoiding planting in fields with high pest densities			X	X	X							
Avoiding skips			X	X	X							
Barriers												
Bed planting												
Bug vacuum												
Compost source	X	X		X						X	X	X
Control volunteer potatoes				X	X	X	X	X	X			
Crop rotation	X	X	X	X	X				X	X	X	X
Cull pile management	X	X	X	X	X	X	X	X	X	X	X	X
Cultivation					X	X	X					
Early harvest							X	X				
Early-maturing varieties								X				
Eliminating host plants												
Eliminating weedy host plants			X	X	X	X	X	X				
Equipment sanitation			X	X	X	X	X	X	X	X	X	
Farmscaping (beneficial planting across farm)												
Fallowing	X	X	X	X	X	X	X	X	X	X	X	X
Fertilizer management			X	X	X	X	X	X	X	X		
Field location and selection	X	X	X								X	X
Flaming for potato vine-kill								X	X			
Flooding	X	X	X								X	X
Grazing												
Hand weeding						X	X	X				
Hand removal of pests						X	X	X				

Cultural Pest Management Activities (continued)

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Harvest techniques								X	X	X		
High hilling					X	X						
High quality, certified seed			X	X	X	X						
Incorporating green manures									X	X	X	
Insectary plantings												
Minimizing leaf wetness						X	X	X	X			
Monitoring canopy moisture, temperature, and humidity					X	X	X	X	X			
Monitoring soil moisture				X	X	X	X	X	X	X		
Monitoring soil temperature				X	X	X	X	X	X	X		
Monitoring temperature and humidity (storage)	X	X	X	X	X	X			X	X	X	X
Mowing				X	X	X	X	X	X			
Mulch												
pH management			X	X	X					X		
Planting clean seed				X	X	X						
Planting cover crops/green manures						X	X	X				
Plant spacing				X	X	X						
Planting date alteration				X	X	X						
Planting depth				X	X	X						
Proper seed cutting				X	X							
Proper soil drainage	X	X	X	X	X					X	X	X
Proper storage	X	X	X	X	X			X	X	X	X	X
Rapid canopy closure							X	X				
Resistant varieties	X	X	X								X	X
Rolling vines and covering with soil								X	X			
Sanitation	X	X	X	X	X	X	X	X	X	X	X	X
Sealing soil cracks								X	X	X		
Trap crops												
Trapping for monitoring					X	X	X	X	X	X		
Variety selection	X	X	X								X	X

Note: Information based on grower experience.

Organic Pesticide Treatment Activities

If an organic pesticide product is sometimes applied, X indicates which month that application occurs for each pest. A blank space indicates that no activity is performed for this pest. The pest still occurs and may be a problem, but activities or treatments are not done because of lack of products or the results from activities may not be efficacious or economically feasible.

Nematodes	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root-knot nematode												
Root-lesion nematode												
Stubby-root nematode												
Insects												
False chinch bug												
Flea beetles					X	X	X					
Green peach aphid												
Leafhoppers												
Loopers, armyworms, cutworms					X	X	X					
Potato psyllids												
Potato tuberworm												
Seedcorn maggot												
Spider mites												
Western spotted cucumber beetle (larvae)												
Wireworms												
Diseases												
Bacterial ring rot												
Black dot												
Black leg-soft rot disease complex				X	X							
Calico												
Early blight												
Early dying												
Fusarium dry rot				X	X	X						
Late blight												
Pink rot												
PLRV												
Powdery mildew												
Powdery scab												
Purple-top mycoplasma												
PVA												
PVX												
PVY												
Pythium leak												
Rhizoctonia/black scurf												
Silver scurf				X	X	X						
Southern blight												
White mold												

Organic Pesticide Treatment Activities (continued)

If an organic pesticide product is sometimes applied, X indicates which month that application occurs for each pest. A blank space indicates that no activity is performed for this pest. The pest still occurs and may be a problem, but activities or treatments are not done because of lack of products or the results from activities may not be efficacious or economically feasible.

Weeds	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Annual grass weeds												
Summer annual broadleaf weeds												
Winter annual broadleaf weeds												
Perennial/biennial weeds												
Canada thistle												
Field bindweed												
Nightshade (Hairy, Cutleaf, Black)												
Nutsedge (Yellow, Purple)												
Quackgrass												
Vertebrates												
California pocket gopher												
Voles and mice												

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

Activity Table for Organic Potatoes West of the Cascades

Field Activities												
Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bed prep			X	X	X	X						
Planting and drag-off				X	X	X						
Organic Fertilizer app.				X	X	X	X					
Hilling/Blind Cultivation					X	X	X					
Cultivation					X	X	X					
Irrigation							X	X				
Vine-kill								X	X			
Harvest							X	X	X	X		
Storage	X	X	X	X	X				X	X	X	X

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

Cultural Pest Management Activities												
Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Aerial monitoring												
Avoiding contaminated water for irrigation							X	X				
Avoid planting in fields with high pest densities												
Avoiding skips				X	X	X						
Barriers												
Bed planting												
Bug vacuum												
Compost source												
Control volunteer potatoes	X	X	X								X	X
Crop rotation												
Cull pile management	X	X	X	X	X	X	X	X	X	X	X	X
Cultivation					X	X	X					
Early harvest												
Early maturing varieties												
Eliminate host plants												
Eliminate weedy host plants			X	X	X							
Equipment sanitation			X	X	X	X	X	X	X	X		
Farmscaping (beneficial planting across farm)												
Fallowing												
Fertilizer management				X	X	X						
Field location & selection	X	X	X	X								
Flaming												

Cultural Pest Management Activities (continued)												
Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Flooding												
Grazing												
Hand weeding						X	X	X				
Hand removal of pests						X	X	X				
Harvest techniques												
High hilling												
High quality, certified, disease-free seed		X	X	X	X							
Incorporate Green Manures												
Insectary plantings												
Minimize leaf wetness												
Monitor canopy moisture, temperature and humidity							X	X				
Monitor soil moisture							X	X				
Monitor soil temperature				X	X							
Monitor temperature and humidity (storage)	X	X	X	X	X				X	X	X	X
Mowing									X			
Mulch												
pH management		X	X	X	X					X		
Plant clean seed				X	X	X						
Plant cover crops/ green manures									X	X		
Plant spacing												
Planting date alteration				X	X	X						
Planting depth				X	X	X						
Proper seed cutting				X	X	X						
Proper soil drainage	X	X	X							X	X	X
Proper storage	X	X	X	X				X	X	X	X	X
Rapid canopy closure					X	X	X	X				
Resistant varieties			X	X	X							
Roll vines and cover with soil												
Sanitation	X	X	X	X	X	X	X	X	X	X	X	X
Seal soil cracks												
Trap crops												
Trapping for monitoring												
Variety selection		X	X	X	X							

Note: Information based on grower experience.

Organic Pesticide Treatment Activities

If an organic pesticide product is sometimes applied, X indicates which month that application occurs for each pest. A blank space indicates that no activity is performed for this pest. The pest still occurs and may be a problem, but activities or treatments are not done because of lack of products or the results from activities may not be efficacious or economically feasible.

Nematodes	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root-knot nematode												
Root-lesion nematode												
Stubby-root nematode												
Insects	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Colorado potato beetles												
False chinch bug												
Flea beetles			X	X	X	X	X	X	X			
Green peach aphid					X	X	X	X	X			
Leafhoppers					X	X	X	X	X			
Loopers, Armyworms, Cutworms					X	X	X	X	X			
Potato psyllids												
Potato tuberworm												
Seedcorn maggot												
Slugs												
Spider mites												
Symphylans												
Western spotted cucumber beetle (larvae)												
Wireworms												
Diseases	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bacterial ring rot												
Black dot				X	X	X						
Black leg-soft rot disease complex												
Calico												
Common scab				X	X	X						
Early blight							X	X				
Early dying												
Fusarium dry rot				X	X	X						
Late blight						X	X	X	X			
Pink rot												
PLRV												
Powdery mildew												
Powdery scab												
Purple-top mycoplasma												
PVA												
PVX												
PVY												
Pythium leak												
Rhizoctonia/Black scurf		X	X	X	X							
Silver scurf			X	X	X							

Organic Pesticide Treatment Activities												
If an organic pesticide product is sometimes applied, X indicates which month that application occurs for each pest. A blank space indicates that no activity is performed for this pest. The pest still occurs and may be a problem, but activities or treatments are not done because of lack of products or the results from activities may not be efficacious or economically feasible.												
Diseases (continued)	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Southern blight												
White mold							X	X	X			
Weeds	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Annual grass weeds												
Summer annual broadleaf weeds												
Winter annual broadleaf weeds												
Perennial/biennial weeds												
Canada thistle												
Field bindweed												
Nightshade (Hairy, Cutleaf, Black)												
Nutsedge (Yellow, Purple)												
Quackgrass												
Vertebrate Pests	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
California pocket gopher												
Voles and mice			X	X	X	X						

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

Nematode Management in Organic Potatoes

This table is a compilation of information concerning the use of cultural controls and inputs for nematodes affecting organic potatoes. All management techniques, whether cultural, biological, or chemical, are part of a larger systems approach. We have indicated whether certain cultural and biological controls contribute to the management of each pest.

Management Tool	root-knot nematodes	root-lesion nematodes	stubby-root nematode	potato cyst nematode	Comments
Cultural Controls					
Avoiding contaminated water for irrigation			*	*	
Avoiding planting in fields with high nematode densities	*	*	*	*	Scouting and field history are critical.
Certified seed	*	*	*	*	First line of defense.
Clean seed	*	*	*	*	All seed areas need to be sampled.
Control volunteer potatoes	*	*	*	*	
Early harvest	*			*	Example: root-knot increases in storage.
Early-maturing varieties	*	*		*	Get potatoes harvested before generations occur.
Eliminate weedy host plants	*	*	*	*	
Fallowing	*	*	*	*	
Flooding	*	*	*	*	
Green manures	*	*	*	*	Species and cultivar specific -- may require multiple treatments.
Nonhost rotation crops	*	*	*	*	
Resistant varieties	*	*	*	*	Extremely important in light of PCN.
Sanitation measures	*	*	*	*	Sanitation always needs to be followed.
Sampling	*	*	*	*	This shows a field's history. The presence of PCN will increase the need for sampling.
Biological Controls					
Burkholderia cepacia	* ?	* ?	* ?	* ?	bacterium
Bacillus chitinosporus	* ?	* ?	* ?	* ?	bacterium
Organic Nematicides					
Use of certain pesticides is allowed under the USDA-NOP regulations, but their use must be explained in each grower's Organic System Plan. The Plan must state that the use of preventive, cultural, mechanical, and physical methods is insufficient, thus requiring the use of an organically-approved pesticide. The list of pesticides below is not an indication of registration for specific pests, but rather it is a list of chemicals that are predicted to help manage pests. We have, however, indicated their general registration on potatoes. Likewise, this list is not an indication of organic approval.					
azadirachtin (several registered products)	?	?	?	?	Spoke with Agroneem company. No research data but widely used by growers with good results. It is extremely important to research these products.
ground sesame plant (Nemagard)	?	?	?	?	It is extremely important to research these products.
meals—rape, sesame, neem, mustard	*	*	*	*	It is extremely important to research these products.

Efficacy rating symbols: ***** = contributes to control, but not a stand-alone practice; **NU** = Not used; **L** = Label claim, but group has no direct experience; **?** = Efficacy not known.

Insect Management in Organic Potatoes

This table is a compilation of information concerning the use of cultural controls and inputs for insects affecting organic potatoes. All management techniques, whether cultural, biological, or chemical, are part of a larger systems approach. We have indicated whether certain cultural and biological controls contribute to the management of each pest. While efficacy information is provided for organic insecticides, it should not be assumed that these are effective stand-alone methods.

Management Tool	Colorado Potato Beetle (CPB)	Flea Beetles	Green Peach Aphid (GPA)	Leafhoppers	Potato Psyllids	Potato Tuberworm	Seedcorn Maggot	Wireworms	Comments
Cultural Controls									
Avoiding planting in fields with high pest densities	F-G	G	NU	NU	NU	F	NU	E	
Avoiding skips	NU	NU	NU	G	NU	F	NU	NU	
Compost	NU	NU	NU	NU	NU	NU	NU	G	
Controlling potato volunteers	G	F	G	F	NU	F	NU	F	
Crop rotation	NU	G	NU	NU	NU	NU	NU	G	
Cull pile management	G	F	NU	NU	NU	G	G	NU	
Eliminating weedy host plants	F-G	G	G	F	NU	P-F	NU	F-G	
Fallowing	NU	NU	NU	NU	NU	NU	NU	F-G	But in Colorado Basin, dry fallow increases wireworm.
Field location	F-G	F-G	P	P	P	F-G	F-G	F-G	
Field sanitation	NU	F	G	NU	NU	G	NU	NU	
Good irrigation techniques	NU	NU	NU	NU	NU	E	NU	F-G	
Hand removal	E	NU	NU	NU	NU	NU	NU	NU	
High hilling	NU	F-G	NU	NU	NU	G-E	NU	NU	
Insectary plantings	NU	NU	E	NU	NU	NU	NU	NU	
Isolation from *Prunus* spp.	NU	NU	E	NU	NU	NU	NU	NU	
Isolation from other potato fields	NU	G-E	G-E	NU	NU	F-G	F-G	F	
Mulch	NU	F-G	NU	NU	NU	NU	NU	NU	
Plant certified seed	NU	NU	F-G	NU	NU	NU	NU	NU	
Plant nutrition management	NU	NU	F-G	NU	NU	NU	NU	NU	
Planting date alteration	F	F	F-G	NU	NU	NU	F	F	Alter plant date so harvest is later.
Planting depth	NU	?	NU	NU	NU	G	G	NU	
Resistant varieties	NU	NU	F	NU	F	NU	NU	NU	If variety is resistant to vectored viruses.

Management Tool	Colorado Potato Beetle (CPB)	Flea Beetles	Green Peach Aphid (GPA)	Leafhoppers	Potato Psyllids	Potato Tuberworm	Seedcorn Maggot	Wireworms	Comments
Cultural Controls (continued)									
Row covers	NU	F	NU	NU	NU	NU	NU	NU	But generally not economically feasible.
Sealing soil cracks	NU	NU	NU	NU	NU	G-E	NU	NU	
Trap crops	NU	P-F	F-G	NU	NU	NU	NU	NU	
Scouting	G	G	G	NU	F-G	F-G	NU	G	
Biological Controls									
Beauveria sp.	F	NU	?	NU	NU	NU	NU	NU	
Bt (*kurstaki*)	NU	NU	NU	NU	NU	F-G	NU	NU	
Bt (*aizawai*)	NU	NU	NU	NU	NU	F-G	NU	NU	
Generalist predators	NU	NU	G	NU	NU	NU	NU	NU	E.g., lacewings.
Metarhizium sp.	NU	NU	NU	NU	NU	NU	NU	?	
Steinernema sp.	NU	F-G	NU	NU	NU	NU	NU	NU	Entomopathogenic nematode.
Organic Insecticides									
Use of certain pesticides is allowed under the USDA-NOP regulations, but their use must be explained in each grower's Organic System Plan. The Plan must state that the use of cultural practices, preventive, mechanical, and physical methods is insufficient, thus requiring the use of an organically-approved pesticide. The list of pesticides below is not an indication of registration for potatoes or for specific pests, but rather it is a list of chemicals that are predicted to help manage pests in potatoes. Likewise, this list is not an indication of organic approval.									
azadirachtin (Azotrol, Agroneem, others)	F	NU	F	F	NU	NU	NU	NU	Several products available.
garlic oil	F-P	NU	NU	NU	NU	NU	NU	NU	Used as a repellent.
oils (cinnamon, clove, cottonseed, peppermint, rosemary, thyme)	?	?	L	L	?	?	?	?	The oils are all premixes of several oils. Some example trade names of these oil mixtures labeled for use on potatoes and insect pests include: Organocide, EF 300, Phyta-Guard EC Insecticide/Fungicide, and Ecotrol EC.
pyrethrins (PyGanic, Diatect V)	F	?	?	?	?	?	?	?	
soap/ potassium salts of fatty acids (Safer Soap, M-Pede)	NU	NU	P	NU	NU	NU	NU	NU	Not effective on GPA; more so on other species. See pages 137-138 in the *Resource Guide for Organic Insect and Disease Management*.

Management Tool	Colorado Potato Beetle (CPB)	Flea Beetles	Green Peach Aphid (GPA)	Leafhoppers	Potato Psyllids	Potato Tuberworm	Seedcorn Maggot	Wireworms	Comments
Organic Insecticides (continued)									
spinosad (Entrust)	E	F	NU	NU	NU	?	NU	?	WSU research shows effectiveness for seedcorn maggot, but growers not using.
sulfur	NU	NU	NU	NU	G	NU	NU	NU	

Efficacy rating symbols: ***** = contributes to control, but not a stand-alone practice; **NU** = Not used; **L** = Label claim, but group has no direct experience; **?** = Efficacy not known; **E** = Excellent; **G** = Good; **F** = Fair; **P** = Poor.

Disease Management in Organic Potatoes

This table is a compilation of information concerning the use of cultural controls and inputs for diseases affecting organic potatoes. All management techniques, whether cultural, biological, or chemical, are part of a larger systems approach. We have indicated whether certain cultural and biological controls contribute to the management of each pest. While efficacy information is provided for organic fungicides, it should not be assumed that these are effective stand-alone methods.

Management Tool	Bacterial ring rot	Black dot	Black leg-soft rot disease complex	Charcoal rot	Common scab	Early blight	Early dying	Fusarium dry rot	Late blight	Pink rot	Powdery scab	Purple-top mycoplasma	PVY	Pythium leak	Rhizoctonia/black scurf	Silver scurf	White mold	Southern blight (stem rot)	Comments
IPM and Cultural Controls																			
Adequate fertility	NU	NU	NU	NU	NU	*	*	NU	*	NU	NU	NU	*	NU	NU	NU	*	NU	
Controlling insect vectors	NU	NU	NU	NU	NU	NU	NU	NU	*	NU	NU	*	*	NU	NU	NU	NU	NU	
Cover crops	NU	*	NU	NU	*	*	*	*	*	*	*	NU	NU	*	*	*	*	*	
Crop rotation	*	*	NU	*	*	*	*	*	*	*	*	NU	NU	NU	*	*	*	*	
Eliminating plant hosts	NU	NU	NU	*	NU	*	*	NU	*	NU	*	*	*	NU	*	NU	*	*	
Equipment sanitation	*	NU	*	NU	NU	NU	NU	*	*	NU	NU	NU	NU	NU	NU	*	NU	*	
Field selection	NU	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Harvest techniques	NU	NU	*	NU	NU	*	NU	*	*	*	NU	NU	NU	*	*	*	NU	*	
High quality, certified, disease-free seed	*	*	*	NU	*	*	*	*	*	*	*	*	*	*	*	*	NU	NU	
Irrigation management	NU	*	*	NU	*	*	*	*	*	*	*	NU	NU	*	*	NU	*	NU	
Minimizing leaf wetness	NU	NU	NU	NU	NU	*	NU	NU	*	NU	NU	NU	NU	NU	NU	NU	*	NU	
Planting at proper depth	NU	NU	NU	NU	NU	NU	NU	*	*	NU	NU	NU	NU	NU	*	NU	NU	NU	
Planting date	NU	NU	*	*	NU	NU	NU	*	*	*	NU	*	NU	NU	*	NU	NU	*	
Proper seed cutting	NU	NU	*	NU	NU	NU	NU	*	*	NU	NU	NU	NU	NU	NU	NU	NU	NU	
Proper soil drainage	NU	NU	*	NU	*	*	*	NU	*	*	*	NU	NU	NU	*	NU	*	NU	
Proper storage	NU	NU	*	NU	NU	*	NU	*	*	*	NU	NU	NU	*	NU	*	NU	NU	
Resistant varieties	NU	NU	NU	NU	*	*	*	NU	*	NU	*	NU	*	NU	NU	*	*	NU	

Management Tool (continued)	Bacterial ring rot	Black dot	Black leg-soft rot disease complex	Charcoal rot	Common scab	Early blight	Early dying	Fusarium dry rot	Late blight	Pink rot	Powdery scab	Purple-top mycoplasma	PVY	Pythium leak	Rhizoctonia/black scurf	Silver scurf	White mold	Southern blight (stem rot)	Comments
Biological Controls																			
Bacillus subtilis (QST 713 Strain) (Serenade Max, Serenade ASO)	NU	NU	NU	NU	NU	NU	NU	NU	L	NU	NU	NU	NU	NU	NU	T	NU	NU	For silver scurf, applied as post-harvest product.
Coniothyrium minitans (Contans)	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	F-G	NU	Soil fungus.
Pseudomonas syringae (Bio-Save 10 LP)	NU	NU	NU	NU	NU	NU	NU	P-F	NU	NU	NU	NU	NU	NU	NU	F	NU	NU	This product has worked better on dry rot than any other products tested to this date. Silver scurf data look very promising.
Saponins of *Chenopodium quinoa*	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	?	NU	NU	NU	
Trichoderma harzianum (T-22 Planter Box) seed treatment	NU	NU	NU	?	NU	NU	NU	?	NU	NU	NU	NU	NU	NU	G-P	T	NU	NU	

Organic Fungicides

Use of certain pesticides is allowed under the USDA-NOP regulations, but their use must be explained in each grower's Organic System Plan. The Plan must state that the use of preventive, cultural, mechanical, and physical methods are insufficient, thus requiring the use of an organically-approved pesticide. The list of pesticides below is not an indication of registration for specific pests, but rather it is a list of chemicals that are predicted to help manage pests. We have, however, indicated their general registration on potatoes. Likewise, this list is not an indication of organic approval.

Management Tool	Bacterial ring rot	Black dot	Black leg-soft rot disease complex	Charcoal rot	Common scab	Early blight	Early dying	Fusarium dry rot	Late blight	Pink rot	Powdery scab	Purple-top mycoplasma	PVY	Pythium leak	Rhizoctonia/black scurf	Silver scurf	White mold	Southern blight (stem rot)	Sprouts	Comments
botanical extract – systemic acquired resistance (SAR) activator (HeadsUp)	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	?	NU	NU	NU	NU	
clove oil (Biox-C)	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	T	NU	NU	F-G	Clove oil is an excellent sprout control when used in combination with the right potato varieties (i.e., long dormancy varieties) and cool storage temperatures.
copper (Champ Formula 2 Flowable, Kocide, others)	NU	NU	NU	NU	NU	G	NU	NU	G	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	No longer controls early blight after potato vines are dead.

Organic Fungicides (continued)

Use of certain pesticides is allowed under the USDA-NOP regulations, but their use must be explained in each grower's Organic System Plan. The Plan must state that the use of preventive, cultural, mechanical, and physical methods are insufficient, thus requiring the use of an organically-approved pesticide. The list of pesticides below is not an indication of registration for specific pests, but rather it is a list of chemicals that are predicted to help manage pests. We have, however, indicated their general registration on potatoes. Likewise, this list is not an indication of organic approval.

Management Tool	Bacterial ring rot	Black dot	Black leg-soft rot disease complex	Charcoal rot	Common scab	Early blight	Early dying	Fusarium dry rot	Late blight	Pink rot	Powdery scab	Purple-top mycoplasma	PVY	Pythium leak	Rhizoctonia/black scurf	Silver scurf	White mold	Southern blight (stem rot)	Sprouts	Comments
hydrogen peroxide/peroxyacetic acid (StorOx)	NU	NU	F	NU	NU	NU	NU	T	P	T	NU	NU	NU	NU	NU	T	NU	NU	NU	All efficacy ratings are in reference to postharvest uses.
mint oil	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	T	NU	NU	F-G	Mint oil is an excellent sprout control when used in combination with the right potato varieties (i.e., long dormancy varieties) and cool storage temperatures.
sulfur (Kumulus, Microthiol Disperss, Mycosin, Thiolux)	NU	NU	NU	NU	NU	NU	NU	NU	F	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	Not a common practice.

Efficacy rating symbols: ***** = contributes to control, but not a stand-alone practice; **NU** = Not used; **L** = Label claim, but group has no direct experience; **?** = Efficacy not known. Additional symbols for biological controls and organic pesticide efficacy rating: **E** = Excellent; **G** = Good; **F** = Fair; **P** = Poor; **T** = Terrible.

Weed Management in Organic Potatoes

This table is a compilation of information concerning the use of cultural controls and inputs for weeds affecting organic potatoes. All management techniques, whether cultural, biological, or chemical, are part of a larger systems approach. We have indicated whether certain cultural and biological controls contribute to the management of each pest. While efficacy information is provided for organic herbicides, it should not be assumed that these are effective stand-alone methods.

Management Tool	Annual Grasses	Summer Annual Broadleaf Weeds	Nightshade (Hairy, Cutleaf, Black)	Winter Annual Broadleaf Weeds	Perennial/Bienneal Weeds	Canada thistle	Field bindweed	Nutsedge (Yellow, Purple)	Quackgrass	Comments
Cultural Controls										
Bed planting	*	P	NE	NE	NE	NE	NE	NE	NE	
Compost source	*	*	*	*	*	*	*	*	*	Compost needs to be weed seed-free.
Crop rotation with alfalfa hay	E	E	E	G	G	G	P	*	*	Summer buckwheat also used to manage Canada thistle.
Cultivation after planting	G	G	G	G	F	*	P	*	*	Nutsedge spreads with cultivation. Cultivation in rotation crops brings quackgrass rhizomes to surface, so they dry out.
Fertilizer management	*	*	F-G	?	NE	NE	NE	NE	*	
Flaming	P	G	G	*	P	NE	P	NE	*	
Grazing	P	*	NE	*	*	NE	*	*	*	Weeder geese for broadleaf weeds and grasses.
Green manures	*	*	F	*	*	*	NE	NU	*	Cover crops help manage Canada thistle.
Hand weeding	E	E	F-G	*	F	F-G	F	*	*	
Harrowing down	G	G	G	*	*	*	*	*	*	
Hilling/blind cultivation	F	G	G	NU	*	*	*	*	*	
Irrigation method	*	F	*	NU	NE	*	*	*	NU	

Management Tool	Annual Grasses	Summer Annual Broadleaf Weeds	Nightshade (Hairy, Cutleaf, Black)	Winter Annual Broadleaf Weeds	Perennial/Biennial Weeds	Canada thistle	Field bindweed	Nutsedge (Yellow, Purple)	Quackgrass	Comments
Cultural Controls (continued)										
Mowing	*	*	NE	*	*	G	NE	*	*	Mowing only used in rotation crops.
Mulch	F	F-G	F	NU	*	NE	NE	NE	NE	
Plant spacing	*	G	*	NU	*	*	*	*	*	
Planting date	*	*	G	NU	*	*	*	*	NE	
Planting depth	*	*	F	NU	*	NE	*	NE	NE	
Primary tillage (pre-plant)	G	*	*	G	G	G	F	*	*	
Rapid canopy closure	*	*	*	NU	*	*	*	*	*	Narrow rows result in quicker row closure.
Sanitation	*	*	*	*	G	*	G	*	*	As pertains to irrigation water.
Stale seedbed	*	G	G	*	NE	NE	NE	NE	NE	
Variety selection (architecture, competitiveness)	*	*	*	*	NE	NE	NE	*	*	
Weed mat	NU	NU	NU	NU	NU	NU	NU	NU	NU	
Biological Controls										
Gall-forming mite *Aceria malherbae*	NU	NU	NU	NU	NU	NU	*	NU	NU	This mite also used for hedge bindweed, but populations are limited to east side of the Cascade Mountains in Oregon.
Weed seed predation (carabid beetles)	*	*	P	P	NE	NE	NE	P	P	Occurs in fields, but not managed.

Management Tool	Annual Grasses	Summer Annual Broadleaf Weeds	Nightshade (Hairy, Cutleaf, Black)	Winter Annual Broadleaf Weeds	Perennial/Bienneal Weeds	Canada thistle	Field bindweed	Nutsedge (Yellow, Purple)	Quackgrass	Comments
Organic Herbicides										
Use of certain pesticides is allowed under the USDA-NOP regulations, but their use must be explained in each grower's Organic System Plan. The Plan must state that the use of cultural practices, preventive, mechanical, and physical methods are insufficient, thus requiring the use of an organically-approved pesticide. The list of pesticides below is not an indication of registration for potatoes or for specific pests, but rather it is a list of chemicals that are predicted to help manage pests in potatoes. Likewise, this list is not an indication of organic approval.										
oil - clove (Matran, BurnOut II)	P	F	G	F	P	P	P	P	P	Control dependent on environment and stage of development.
oil - cinnamon, clove (Weed Zap)	P	F	G	F	P	P	P	P	P	"

Efficacy rating symbols: ***** = contributes to control, but not a stand-alone practice; **NU** = Not used; **NE** = Not effective; **L** = Label claim, but group has no direct experience; **?** = Efficacy not known; **E** = Excellent; **G** = Good; **F** = Fair; **P** = Poor.