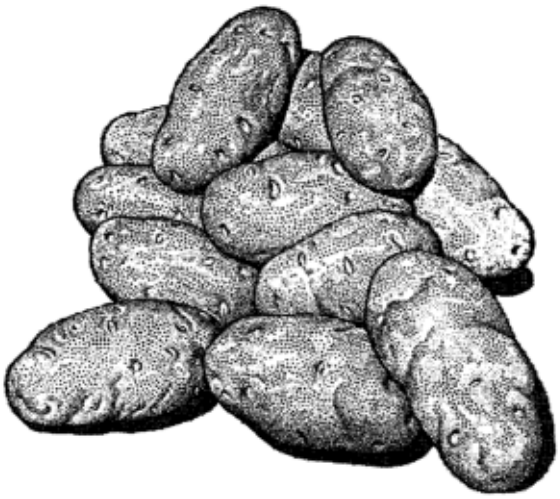
A Pest Management Strategic Plan for Potato Production in California



August 2005

The California Potato Research Advisory Board (CPRAB)

Monfort Management Services (MMS)

Monfort Management Services and the California Potato Research Advisory Board received support for this project from the Western Integrated Pest Management Center at UC Davis.

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Executive Summary

The California potato industry, representing statewide fresh (conventional and organic), chipper, and seed production, met in March of 2005 to begin the process of developing a strategic plan to address the long term pest management needs of the industry. Two one day meetings were held that included growers, pest control advisors (PCAs), handlers, and University of California Research and Cooperative Extension personnel. The input from these meetings, along with commodity statistics on potato production in California, has been summarized.

This document has been developed in response to several regulatory actions (e.g., Food Quality Protection Act, methyl bromide phaseout, etc.), which will potentially impact availability and/or use of pest management products used by growers. In addition, new pests are emerging and/or new technologies must be incorporated into efficient production systems, which are protective of consumers, workers and the environment. The California potato industry wishes to be proactive in its approach to crop and pest management.

This strategic plan will facilitate the transition to "Reduced Risk" pest management by the California potato industry. "Reduced Risk" broadly describes pest management techniques and tools that have low inherent toxicities and minimal impact on the environment. This long term approach to pest issues will also help the California potato industry work more effectively with the Land Grant University research and extension systems that are currently experiencing severe budget reductions. All resources must be utilized in the most efficient manner possible; this plan will help the grower community to direct resources to address the most critical issues of the California potato industry.

This document includes an overview of potato production practices, seasonal pest occurrences and evaluations of pest management techniques and practices used throughout California. This plan addresses both current and emerging pest management needs; it is a working document and will need to be updated periodically. Efficacy ratings of various pest control techniques (chemical and non-chemical) used in potato production have been summarized from input made by growers, pest control advisors, university researchers and other experts involved in field activities.

This strategic plan principally serves as a guideline to address the most important issues of the California potato industry as identified by the growers themselves. A list of industry experts (growers, pest control advisors, industry representatives, and university research and extension personnel) is included in this document to serve as a reference for those needing more information regarding California potato production.

The foundation for the strategic plan is the Crop Profile for California Potatoes (draft form) and the UC Pest Management guidelines for potatoes (http://www.ipm.ucdavis.edu/PMG/selectnewpest.potatoes.html).

Stakeholder Recommendations

As a result of the meetings held in March, 2005, the California potato work group identified the following research, regulatory and educational priorities for their industry.

RESEARCH	• **Tuber moth monitoring** • **White mold control** • **Alternative fumigants and alternatives to fumigants** • **Optimizing efficacy of Oxamyl (Vydate)** • **Improved nightshade herbicides** • **Erwinia/Bacterial problems** • **Improved control of potato storage rot** • **Pre-emergent herbicides in high organic matter soil** • **Irrigation management** • **Improved pest resistant varieties** • **Use of flooding for pest control**

REGULATORY	• **Harmonizing registrations between the federal and state level** • **Metam-sodium (Vapam) regulations take into consideration the differences between regions in the state**
EDUCATION	• **Concern over impact of county bulletins (endangered species)** • **Irrigation management**

The California potato industry intends that this document be used as a resource by USEPA, USDA, CDPR and other agencies as they inquire about pest management issues, needs, and practices in California. This strategic plan will be periodically updated to remain current with industry developments and issues. For follow-up inquiries, contact information for work group members is provided in the Appendices.

The California potato industry appreciates the support of EPA, USDA, CDPR, and the University of California land grant system throughout the development of this strategic plan. We look forward to the valuable assistance provided by these agencies and institutions as we develop solutions for the issues facing the California potato industry.

The mention of any product in this document does not represent endorsement by the California Potato Research Advisory Board or any member of the California Potato Work Group.

Chemical and trade names for products used in potatoes are listed in the efficacy tables in the Appendices.

The California Potato Research Advisory Board (CPRAB)

Monfort Management Services (MMS)

AUGUST 2005

California Potato Production Overview

Production figures.* California ranks 9th compared to the other potato producing states with 3% of the total US production.

Crop Year	Planted/harvested	Yield Per Acre	Production	Value Per Unit	Total Value
1999	43,200	376	16,227,000	11.80	190,057
2000	44,000	380	16,710,000	12.50	209,455
2001	35,900	367	13,188,000	14.20	186,139
2002	43,600	391	17,069,000	17.50	297,346
2003	43,000	402	17,295,000	14.80	253,610
5 year average	**41,940**	**383**	**16,097,800**	**14.16**	**227,321**

***California Agriculture Statistics Service (ftp://www.nass.usda.gov/pub/nass/ca/AgStats/2003cas-fld.pdf)

Production areas. Potatoes are grown year round in California due to the state's unique geography and climate. Potatoes are classified by harvest season, skin type, and intended market use. Market use classification includes fresh market, processing, seed potatoes, and specialty varieties for local farmer markets. Spring, summer, fall, and winter potatoes are harvest classifications while reds, russets, yellows and whites are skin type. All classifications of potatoes are grown within four major potato-growing regions in the state.

Fresh market potatoes are the main type of potatoes grown in Kern and Los Angeles Counties, but a significant amount of processing potatoes are also grown in Kern County for chipping. Processing potatoes include potatoes grown for processing into chips of French fries, commonly known as chippers, and potatoes grown for frozen products. They have a high specific gravity, low sugar content, thin skin and a uniform round shape.

A limited amount of specialty potatoes are grown in Kern County for local and Los Angeles farmer markets, and the expanding regional and national specialty produce market. The winter-harvested crop is stored in the ground, enabling the season to be extended without the cost of artificial storage.

The other major growing areas are the Klamath/Tulelake Basin in Siskiyou and Modoc Counties, the Delta Basin in San Joaquin County, and the desert and mountain valleys of Imperial, Riverside and San Diego Counties.

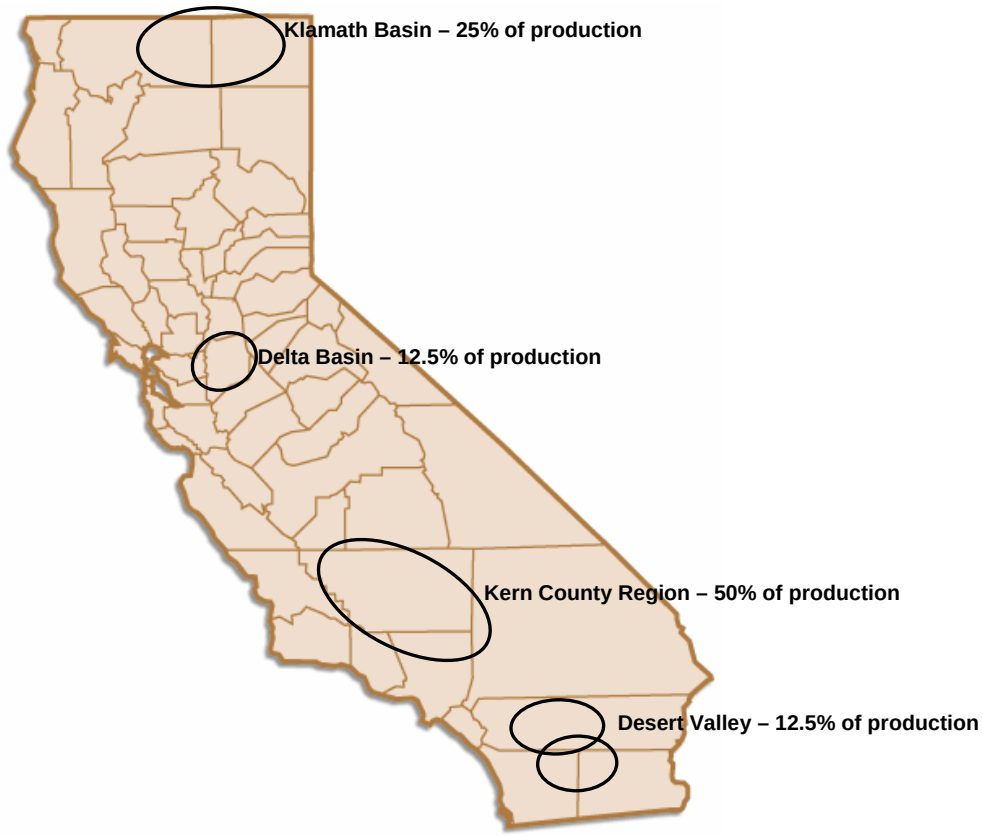
Klamath Basin growers produce fresh market, processing, and seed potatoes. Most potatoes are stored in modern atmosphere controlled buildings, making it unique from the other potato growing regions of California. The California side of the Klamath Basin has soils with organic matter contents up to 13%.

The third area of potato production is the Delta region where a high percentage of the potatoes are grown for seed. Seed potatoes are not seeds of potatoes, but small tubers that are produced in a specific prescribed and monitored system. Potatoes from the Delta are grown on muck soils, which differ significantly from the mineral soils that are found in the other areas.

The fourth major production area is southern California, where several desert and mountain valleys are used to enable harvest during most of the year. The desert production is the first area planted in California – November and December – and the first harvested – April and May. All of the southern California production is devoted to fresh market reds, whites and yellows (i.e. no russets).

Other minor production areas include the South Coast, Central Coast, central San Joaquin Valley, and Sacramento Valley, where specialty types are grown for local and specialty markets.

California Potato Production Regions



Counties of Production

Klamath Basin	Modoc, Siskiyou
Delta Basin	San Joaquin
Kern County Region	Kern, Los Angeles, Santa Barbara, Ventura
Desert Valleys	Imperial, Riverside, San Diego

Production Practices. The majority of potatoes produced in California are spring potatoes grown in Kern County Region. Potatoes in the Klamath Basin are grown for a fall harvest while most of the Delta's seed potatoes are harvested in the summer. Normally, certified seed is brought into California for planting from various locations, including Washington, Oregon, Idaho, Colorado, Nebraska, and Canada. A significant amount of seed from California is also used. Seed potatoes are cut into seed pieces and usually treated with a fungicide soon after cutting to protect from various seed and soil borne diseases such as *Rhizoctonia,* silver scurf, and *Fusarium* dry rot. After treating, the seed pieces may or may not be allowed to form a suberized layer over the cut surfaces. This process, called healing, provides a physical barrier from soft rot and seed piece decay. The seed is planted mechanically into pre-irrigated beds at a depth of 6 to 8 inches and often fertilizer is side dressed in the same operation.

The majority of potatoes grown in California are sprinkler irrigated by solid set sprinklers. Center pivots and linear sprinkler systems are also commonly used. A limited amount of acreage may be furrow irrigated in the lower desert. In the Delta, fields are irrigated by controlling the amount of water that is pumped out of the field due to the high water table. Sprinkler chemigation is normally used for additional applications of fertilizer and may be used for the application of herbicides, fungicides, and insecticides. Potatoes receive frequent irrigations during a growing season due to the plant's shallow root system, sensitivity to moisture stress, and the sandy loam soils they are commonly grown on.

The use of soil fumigants such as Vapam provide (through a single application) control of a wide range of pests. Soil fumigants reduce the need for multiple applications of multiple pesticides for a wide range of pests and diseases.

Before the harvest of fresh market potatoes, the tops are killed by mechanical or chemical means or by frost and the fields are allowed to dry slightly. These steps allow the skin to toughen and mature so that they can be harvested with a minimum of skinning and bruising. Two or three days before harvest the fields are lightly irrigated to loosen the soil and then the potatoes are mechanically harvested. Skin set is not normally a concern in processing and seed potatoes so their tops are mechanically removed just before harvest. Yields range from 250 to 460 cwt. per acre depending on season and type of potato.

Potatoes grown in Klamath Basin are harvested and shipped immediately or placed into storage facilities and marketed at a later date. Potatoes grown elsewhere in the state are shipped to market or processing plants soon after harvest.

- There are 3 major categories of potatoes produced in California:

  Statewide estimate: 60% fresh, 35% chipper, and 5% seed

  Klamath Basin: fresh 50%, chipper 45%, and seed 5%

  Kern: 70% fresh, 25% chipper, and 5% seed
- An estimated 98% of the potato crop from the Klamath Basin is consumed domestically and approximately 2% is exported.
- An estimated 90% of the potato crop from the Kern Region is consumed domestically and approximately 10% is exported (mostly to Canada and Mexico).
- An estimated 95% of the statewide production is consumed domestically and approximately 5% is exported.
- Approximately 1-5% of California potatoes are produced using organic production methods.
- Diseases are the major pest threat to potatoes.

Integrated Pest Management. Many potato pests and diseases may be transmitted in seed tubers used for planting. Growers may avoid serious problems by purchasing pest and disease free seed. Use of clean seed may also delay the introduction of serious soil borne pests and diseases to the field. Many states have seed certification programs that quantify the levels of certain diseases and pests in certified seed lots. Growers need to become familiar with the certification programs in states where seed is produced and need to develop a close relationship and trust with seed producers to assure they are getting the cleanest seed possible. Serious problems, which may be transmitted in seed, include nematodes, wilt diseases, potato viruses, scab, blackleg, late blight, and bacterial ring rot.

Careful field selection is another way of reducing the risk from serious pest or disease problems. Fields with a history of root knot nematode, Verticillium wilt, white mold, or other serious soil borne pathogen should be avoided, if possible. Good crop rotation and increasing the number of years between potato crops will reduce many of these problems.

Care should be taken to assure that heavy organic matter residues (stubble) from the previous crop have sufficient time to decompose in the soil before planting potatoes. The presence of freshly breaking down organic matter at the time of potato planting can lead to serious problems with difficult to control insect pests such as corn seed maggot.

Trade Issues

1. There is a lack of consistent access to information on Canadian seed sources, which results in the inability to trace diseased seed back to its origin.
2. Political trade barriers including phytosanitary requirements on imports and difficulties in shipments going into Mexico from the Kern County region due to claims of Bacterial Ring Rot (BRR) contamination, even though it has never been found in Kern County.

GMO

GMO varieties have the potential to manage many of the major pests of potatoes and potentially reduce the use of high risk pesticides; however, public perception and market resistance prevent those from being grown at this time.

Endangered Species

An endangered species is any plant or animal species whose ability to survive and reproduce has been jeopardized throughout all or in a significant portion of its historical range. Species listed as endangered are those species whose population levels have declined to such an extent that any further decline may result in the extirpation of the species. Therefore protecting endangered species from adverse effects that may jeopardize population stability is very important to maintain the sustainability of the species. Adverse effects include over harvesting, competition from exotic and invasive species, changes in climate, loss of habitat and exposure to contaminants such as pesticides.

The production of crops, including potatoes, does create some hazards that may interfere with the continued well being of any wildlife species and in particular endangered species. Exposure to pesticides used in potato production is one of the prominent and easily recognizable hazards that should concern potato producers. Potato producers have many tools and techniques they can utilize to reduce the potential for exposure mitigating the hazards associated with pesticides.

The safest technique to reduce exposure is to apply pesticides only when the need can be justified based on established economic thresholds combined with knowledge of the local area. If at all possible apply pesticides when a species is not likely to be present in or near the application site. If the species is expected to be present in or near the application area risk can be minimized by using the least toxic chemical(s) that will control the target pest, reducing the application rate to the minimum needed to control the target pest, minimize the number of applications per season, and increase the application interval. Also pesticide drift into sensitive habitats can be minimized by maintaining a no treatment buffer between sensitive habitats and the nearest edge of the treatment site, and using appropriate application techniques and tools.

Major Pests of Potatoes in California

Diseases are the most important pest problem in the production of potatoes in California. Potatoes can be infected by a number of different types of microorganisms including viruses, mycoplasmas, bacteria, and fungi. Infections by plant pathogens can occur at any growth stage of the plant and infect the foliage, stems, and tubers. Because of this, most of the pesticide applications are made for control of plant diseases. Diseases that cause tuber decay can cause great losses in storage and during tuber shipment to markets.

Cultural practices are the primary and often most effective way to control disease infestation. These practices include, but are not limited to:

- Using certified seed
- Good rotational practices
- Use of broad spectrum soil fumigants
- Use of fungicides
- Removal of crop residues
- Good husbandry practices
- Good cultural practices
- Irrigation management
- Fertilizer
- Control of insects/vectors
- Use of biological controls--antagonistic (micro) organisms

Insect pests that attack the tuber, seed pieces, or foliage vary in importance from region to region. When outbreaks of insect pests do occur they are usually limited to localized areas. Tuberworm, psyllid, symphylans, worms, and leafhoppers can all have devastating effects on potatoes. The most important pest changes by year and by location. Aphids are of particular concern due to their ability to transmit viruses.

Diseases	Late Blight, Early Blight, Stem and Stolon Canker caused by *Rhyzoctonia*, White Mold (*Sclerotium rolfsii, Sclerotinia sclerotium*, *Erwinia*, Pink Rot, *Phytophthora*, *Pythium*, *Fusarium*, most potato viruses, Powdery and Common Scab
Insects	Aphids, Cutworm, Armyworm, Looper, Tubermoth*, psyllid, leafhoppers, symphylans, wireworms, flea beetles
Nematodes	Root Knot, Stubby Root, Lesion
Weeds	Nutsedge, Cheeseweed (*Malva*), Johnsongrass, Nettle, Purslane, Lambs quarter, Nightshade, Pigweed, Mustard, Wild Oats, Kochia, Canada Thistle, Brassica, annual grasses, volunteer cereals, Quackgrass
Vertebrates	Voles, mice

*Due to increasing pressure in the Pacific Northwest of this pest, the Klamath Basin area is very concerned this pest will soon be a problem.

Stages of Crop Development

Klamath

Bed Preparation	Planting	Emergence	Row Closing	Harvest
Varies	3 – 20 days	20 – 30 days	60 – 75 days	90 – 140 days

Kern County Region (reported in days from planting)

Bed Preparation	Planting to emergence Pre-emergence	Emergence to row closing	Row Closing to harvest
Varies	10 – 60 days	40 – 80 days	90 – 160 days

Potato varieties can be generally grouped into early (90 to 120 days), and late varieties (110 to 160 days). This varies according to planting season (i.e., spring or fall).

A PEST MANAGEMENT STRATEGIC PLAN FOR CALIFORNIA POTATOES

Growth Stages

The work group identified several distinct phases that are important to horticultural and pest management events in potato production. These include:

- Site Selection and Bed Preparation
- Planting
- Pre-emergence
- Post-emergence
- Row closure
- Bulking (sizing)
- Vine kill
- Harvest
- Post-harvest (Tuber Handling and In-field activities)

The following section tracks potato development under California conditions and provides information on typical field activities and important pest issues during these intervals.

Site Selection and Bed Preparation

Cultivation of the seedbed to a depth of 12 inches or greater is important to ensure good drainage and adequate soil aeration for tuber growth. Cultivation at the proper soil moisture is critical to avoid clod formation. The beds can be pre-formed before planting or made by mounding soil onto the potato rows after planting and emergence. The final result, in either method, should be high, wide beds (e.g. 12" high, 18-24" wide) to allow for maximum root and tuber growth, maximum water retention, and prevention of tuberworm infestation. During the early season, at least, the beds should be cultivated, for weed control, creating a hill (mound) to cover the developing tubers, preventing greening, and providing an environment conducive to growth

Cultural and Worker Activities

• Primary tillage	• Pre-emergent herbicide applications (spring)
• Pre-irrigation	• Nematode sampling (fall)
• Metam Sodium (Vapam) & Oxamyl (Vydate) applications (fall/spring)	• Soil fertility (fall or spring)

Diseases

Maintaining good soil tilth and structure is important to soil drainage, aeration and disease prevention. Soil conditions, such as compaction, plow pans and perched water tables can inhibit drainage and may lead to water lodged soils and poor aeration. Such conditions increase the incidence and severity of many soil borne pathogens including *Verticillium* (early dying), *Phytophthora* (pink rot), *Pythium* (leak) and *Erwinia* (soft rot).

Viruses

Potato mosaic viruses (potato virus A, X, Y, and others) cause mosaic symptoms that vary widely with virus strain and potato cultivar. Potato virus Y is the most severe of the mosaic viruses. Symptoms include mottling or yellowing of leaflets, leaf crinkling, and sometimes leaf drop. The presence of more than one of the viruses in a plant usually affects the types

of symptoms and increases symptom severity. A severe crinkling of the leaves occurs when potato viruses Y and X occur in the same plant. All of these viruses are transmitted through infected seed; thus, the use of certified seed, which has no to very little infection, is the most important strategy for disease management. Most of these viruses are also transmitted plant-to-plant by many species of aphids. Because the aphids retain the ability to transmit these viruses for very short periods of time, spread is often very rapid and localized. In general, spread of these viruses in the field occurs when aphid activity in fields is high. Therefore, insecticides are used to prevent the buildup of aphid populations. Some of these viruses have wide host ranges, including other crops and many weed species. Because outbreaks of virus diseases are unpredictable from year to year and for various geographic locations, the control of these diseases is difficult.

Cultural Control: Control of weeds and volunteer potatoes surrounding potato fields may help management of these viruses. When possible, resistant cultivars should be used. Do not plant potatoes near crops heavily infested with aphids and infected with viruses.
Biological Control: none
Chemical Control: none

Blackleg (*Erwinia carotovora* var. *atroseptica*): Blackleg inoculum comes primarily from infected seed tubers, but it may also be spread in infested soil, contaminated irrigation water, and by insects. Blackleg is favored by cool, wet conditions at planting followed by high temperatures after emergence.

Cultural Control: Good drainage must be provided and over irrigating is avoided. Cull piles and potato volunteers in rotation crops and adjacent fields are eliminated.
Biological Control: none
Chemical Control: none

Calico (Alfalfa Mosaic Virus): Alfalfa mosaic virus is transmitted by many species of aphids. Transmission of the virus is most likely to occur when aphids migrate into potato fields from nearby alfalfa or clover fields, the usual hosts for this virus. Infection often occurs on edges of fields located near alfalfa. Little or no secondary spread occurs within the potato field.

Cultural Control: none
Biological Control: none
Chemical Control: none

Common Scab (*Streptomyces* spp.): Widely distributed and persists in soil on decaying organic matter. Inoculum is also carried on infected seed tubers. Continuous cropping to potatoes usually increases disease severity. Tubers become susceptible to infection when they start forming. Scab lesions expand as the infected tubers grow. Mature tubers with well-developed skins are not susceptible. The fungus can also persist in non-composted manure from animals that have fed on infested tubers. When done properly, however, composting can apparently destroy infective inoculum of *Streptomyces.* Infection is favored by warm dry soils. A relatively low soil pH (5.5) inhibits scab, but *S. acidiscabes* can cause scab in soils at less than pH 5.5.

Cultural Control: Maintaining high soil moisture (80-90% of available water storage) during tuber initiation and the 6 to 8 weeks that follow reduces the severity of scab and usually controls the disease adequately. Other practices that help reduce the incidence of scab include crop rotation with green manure crops such as rye, millet, and oats, whereas, rotations with carrots, beets, spinach, turnip, and radish are not advisable. Soil application of animal wastes, which favors scab development, is avoided. Certified seed tubers free from common scab should be used. When applied before or at planting, some soil amendments such as sulfur, gypsum, and triple superphosphate, suppress common scab.
Biological Control: none
Chemical Control: none

Corky Ringspot (Tobacco rattle virus): Transmitted by stubby root nematodes (*Paratrichodorus* spp.). Young potato roots and tubers are infected with tobacco rattle virus when virus-infected nematodes feed on them. The virus is also transmitted in infected tubers. Other hosts of the virus include nightshades, pigweeds, shepherd's-purse, purslane, cocklebur, and sunflower.

Cultural Control: Certified seed tubers are planted and fields with a history of corky ringspot are avoided.
Biological Control: none
Chemical Control: Fumigation with Metam-Sodium (Vapam)(good) or 1,3-dichloropropene (Telone) (fair to excellent depending on soil type).

Curly Top (Sugarbeet Curly Top): The virus is transmitted by the beet leafhopper (*Circulifer tenellus)*. Curly top affects a wide range of crops and weeds. Both the virus and the leafhopper survive on a large number of wild plants and weeds.

Cultural Control: To prevent curly top outbreaks, the California Department of Food and Agriculture carries out a statewide monitoring and treatment program for the beet leafhopper vector. Beet leafhopper populations are monitored in foothill areas in spring. Locations where high populations have congregated are sprayed before they can move into agricultural fields. Treatment of beet leafhopper by growers is not suggested for preventing curly top.
Biological Control: none
Chemical Control: none

Early Blight (*Alternaria solani*): Early blight causes infection of both tubers and foliage and can result in severe yield loss in all potato growing regions of California. Foliage of diseased plants develops characteristic circular to angular lesions with concentric rings. Stressed and senescing plants are more prone to infection.

Cultural Control: Adequate fertilization and watering helps to avoid plant stress that can lead to early blight infection. Slower growing varieties may be less prone to becoming stressed.
Biological Control: none
Chemical Control: none

Fusarium Dry Rot and Seed Piece Decay (*Fusarium* spp.): *Fusarium* spp. is present in all soils and is found on the surface of all tubers. Wounds are required for infection. Proper handling and curing is usually sufficient to give economic control of dry rot in storage. Allow tubers to mature before harvest and prevent bruising tubers during harvest and storage operations. Fresh market tubers should be stored at 38^{o} to 40^{o} F with 90 to 95% relative humidity and adequate ventilation.

Cultural Control: Clod size is reduced to foster proper soil tilth.
Biological Control: none
Chemical Control: Soil of fumigated with an application of (Metam Sodium) Vapam.

Late Blight (*Phytophthora infestans*): Late blight is the disease of greatest concern to growers. New strains of the fungus have developed that are resistant to previously effective materials. The new strains are also more aggressive and able to cause infection over a greater environmental range than previous strains.

Cultural Control: none
Biological Control: none
Chemical Control: none

Leafroll: Potato leafroll virus can be introduced to a potato field by infected seed tubers or by aphids that have fed on infected potato plants. The most efficient vector of the virus is the green peach aphid. Several minutes to hours are required for the aphid vector to acquire the virus, but once the virus has been acquired, the aphid carries the virus for life. Winged aphids carried in air currents spread the virus for long distances between fields, and nonwinged aphids are important in plant-to-plant spread. Aphid feeding introduces potato leafroll virus into the phloem tissue where the virus multiplies, spreads, and initiates disease. Potato leafroll virus is not transmitted mechanically by machinery or contact with leaves.

Cultural Control: Volunteers are reduced and weed hosts alternated.
Biological Control: none
Chemical Control: Chemical control of potato leafroll virus is aimed at controlling aphids in order to reduce spread of the virus within a field.

Leak (Water Rot) (*Pythium spp*.): Leak is not a common problem but considerable loss can occur to fields under wet soil conditions. Leak causes a spongy, wet internal rot of tubers. The fungus enters through wounds made at harvest and can be a problem in storage.

Cultural Control: Soil is tilled to ensure proper soil tilth and drainage.
Biological Control: none
Chemical Control: Soil is fumigated with an application of Metam Sodium (Vapam).

Pink Rot (*Phytophthora erythroseptica*): Pink rot is a common problem to potatoes grown in the Klamath Basin area, but can be occasionally found elsewhere. The fungus survives in the soil and is promoted by saturated soils. Infected tubers begin to decay at the stem end in the field or through the eyes in storage. Internal decayed tissue becomes rubbery and may develop a pink cast after a few minutes exposure to air. Pink rot can spread in storage.

Cultural Control: Soil is tilled to ensure proper soil tilth and drainage. Fields becoming saturated for long periods of time is avoided. Good air circulation and storage temperatures kept below 40EF can slow storage spread.
Biological Control: none
Chemical Control: Soil is fumigated with an application of Metam Sodium (Vapam).

Powdery Scab (*Spongospora subterranea*): Tubers infected with powdery scab develop small purplish-brown pustules. Powdery scab causes galls on roots and stolons also. The inoculum that initiates powdery scab can originate from infected seed tubers or infested soil. Once *Spongospora subterranea* is introduced into a soil, its resting spores survive indefinitely (3 to 50 years). The fungus can also persist in non-composted manure from animals that have fed on infested tubers. When done properly, however, composting can apparently destroy infective inoculum of *S. subterranea*. In the presence of susceptible potato roots, resting spores can germinate and release swimming zoospores that infect the host. Infection and disease development are favored by cool, wet conditions.

Cultural Control: Seed tubers affected by powdery scab are not planted. Sites with a history of the disease are avoided. Susceptibility varies among red and white varieties. Rotations out of potatoes for 3 or more years may be beneficial on some infested sites. Planting occurs in well-drained soils and over-irrigation is avoided.
Biological Control: none
Chemical Control: In fields with a history of powdery scab, preplant chemigation with metam sodium (Vapam) can reduce disease in a subsequent crop of potatoes.

Southern White Rot/Sclerotium Stem Rot (*Sclerotium rolfsii*): Appearance of Southern white rot can be confused with white mold. Southern white rot produces a denser, compact mat of mycelium than white mold. The sclerotia of Southern white rot are smaller and more round and are initially white but then become brown. They both attack the plant at the soil line, but Southern white rot will grow below the soil and rot the tubers as well as the stems. Stem infection leads to wilting and yellowing of the foliage. The fungus infects tubers via stolons and causes a moist, cheesy decay. Southern white rot is favored by warm conditions (80-90EF) and wet soils. Significant losses can occur in the Kern County region and the lower deserts.

Cultural Control: Early planted fields avoid the problem by being harvested before the warmer temperatures of early summer occur. Amendments with ammonium help by killing the mycelium in the soil. Ammonium bicarbonate applications late in the season may help prevent tuber infection.
Biological Control: none
Chemical Control: Fields with a history of Southern white rot can benefit from fumigation with Metam Sodium (Vapam).

Stem and Stolon Canker (*Rhizoctonia solani*): This disease is a common problem to most growing regions, but the amount of damage varies greatly. The fungus (*Rhizoctonia solani*, AG-3) is able to survive in the soil particularly in the cool Klamath Basin. In warm production areas tuber borne sclerotia are probably the most important source of inoculum. Stem and stolon canker can reduce plant stand and vigor. Aboveground symptoms include yellowing, purpling and an upward curling of leaves. Below ground, the fungus causes red-brown lesions that develop into sunken cankers. Infected tubers may become misshapen and unmarketable.

Cultural Control: The use of certified seed reduces the amount of inoculum that is brought on the seed. Soil borne inoculum levels can be reduced by proper crop rotations.
Biological Control: none
Chemical Control: Soil is fumigated with an application of Metam Sodium (Vapam). Other pesticides used include Thiophanate-methyl (Tops) and Fludioxonil (Maxim).

White Mold (*Sclerotinia sclerotiorum*): White mold can be confused with Southern white rot. Both produce mats of mycelium along with sclerotia. White mold has a whiter and fluffier mat of mycelium and the sclerotia are irregular in shape and black. White mold is also active in cooler temperature (60 to 70EF). Both attack plants at the soil line. In severe infections, the stem is girdled and plants die. Although common in all potato growing regions of California, it is more serious and common in the Klamath Basin.

Cultural Control: Excessive amounts of water and fertilizers produce overly dense canopies, which should be avoided.

Biological Control: none
Chemical Control: Effective control with chemicals is difficult because the fungus is at the soil line and appears after the canopy closes.

Work Group Recommendations for Disease Management -- Site Selection and Bed Preparation

RESEARCH	• Alternatives to Metam-Sodium (Vapam) (particularly for wildlife critical habitats) • Green manures/fallowing • Flood fallow
REGULATORY	• Consideration of differences between areas of the state for Metam-Sodium
EDUCATION	• Consideration of differences between areas of the state for Metam-Sodium

Insects

Seed corn maggot
Cultural Control: Freshly decomposing organic matter at planting is avoided.
Biological Control: none
Chemical Control: none

Cutworms: Black cutworm (*Agrotis ipsilon*) and **Variegated cutworm** (*Peridroma saucia*):
Cultural Control: Weed control in and around the field before planting will reduce cutworm problems through reduction of early season host plants.
Biological Control: none
Chemical Control: none

Wireworms: Pacific coast wireworm (*Limonius canus*), **Sugarbeet wireworm** (*L. californicus*) and **Dryland wireworm** (*Ctenicera pruinina*): Wireworms feed on seed pieces and young root systems during stand establishment, resulting in poor stands. Later in the season wireworms can bore into tubers causing them to be misshapen, lowering their quality and value.

Cultural Control: Monitoring for wireworms when making site selection decisions. Wireworms can be a problem following pasture or alfalfa. A dry fallow period between crops will help to lower the population of wireworms in the soil.
Biological Control: none
Chemical Control: Ethoprop (excellent) and Diazinon (poor) can be used to reduce wireworm levels in the soil. The chemical material needs to be incorporated into the soil by tillage before planting. Fumigation will also provide partial control to wireworm along with other pests such as nematodes and weeds.

Work Group Recommendations for Insect Management -- Site Selection and Bed Preparation

RESEARCH	• Techniques for predicting the migration of black cutworms • Model to predict egg laying and plant damage for the black cut worm • Pre-plant incorporation of Vydate • Development of and research on newer pesticide chemistries and or biological control
REGULATORY	• Determining ongoing registration status of Ethoprop (Mocap)
EDUCATION	• No recommendations

Nematodes

The following measures will help prevent spread of nematodes to uninfested fields: (1) using certified planting material; (2) cleaning soil from equipment before moving between fields; (3) keeping irrigation water in a holding pond so that any nematodes present can settle out and pumping water from near the surface of the pond; (4) preventing/ reducing animal movement from infested to uninfested fields; and (5) composting manure to kill any nematodes that might be present before applying it to fields.

Columbia root knot nematode (*M. chitwoodi*) (Race 1, Klamath Basin)
Lesion nematode (*Pratylenchus penetrans*) and (*P. neglectus*)
Northern root knot nematode (*Meloidogyne hapla*) (not in desert regions)

Southern root knot nematode (*M. incognita*) (most prevalent of the nematodes in the San Joaquin Valley)
Stubby root nematode (*Paratrichodorus sp.*)

Several species of nematodes are parasitic on potatoes, but root knot nematodes are the most common and damaging nematode to potatoes grown in California. Different species of root knot can be found in all the potato growing regions. Besides root knot nematode (*Meloidogyne* spp.), stubby root nematode (*Parathrichodorus* spp.) and lesion nematode (*Pratylencus* spp.) are of economic importance to the potato industry in California.

Because of their biology and wide host range, nematodes in general are difficult to control. Root knot nematodes can reduce vigor of plants and cause warts and bumps on the surface of tubers. Lesion nematodes can cause numerous lesions on the roots and reduce yields and may enhance infection with verticillium wilt, but are normally not considered of great importance in potatoes. Stubby root nematodes cause the roots to become short and stunted. Stubby root nematodes are also able to transmit tobacco rattle virus.

Cultural Control: Crop rotations can be used but because of the wide host range of nematodes careful consideration of alternative crops is required. It is also often required to know which species of nematode is present in the field to select an effective rotation crop. Fallow rotations may be more effective than a crop rotation but the land must be taken out of production for a period of time. Cultivating the soil to remove the weeds is required to eliminate those as alternate hosts. Date of planting can be effective on some species of root knot nematode. *Meloidogyne incognita* is much more active in warm soils than *M. hapla* or *M. chitwoodi*. Planting during the coolest time of the year may avoid *M. incognita* at harvest time. The opposite would be true for avoiding *M. hapla* and *M. chitwoodi*. Again, knowing which is the predominate species in a field would be required before this method of control can be used. Nematodes cannot move any great distance. Nematodes are moved to new areas and within a field by equipment, infected tuber, and irrigation water. Sanitation practices that help slow the spread of nematodes are effective. This includes cleaning equipment, using certified seed, and settling ponds when tail water is used in infested fields. More damage occurs the longer that the tubers are left in the ground. Harvesting the tubers as early as possible helps to minimize that amount of damage caused by nematodes. Cover, non-host, and trap crops can be effective tools.
Biological Control: none
Chemical Control: Fumigants are the best method of control for nematodes and are the most common chemical treatment used for their control. Good tillage and proper soil moisture are important for fumigants to be most effective. Materials banded into the seed row before or at planting include, Metam Sodium (Vapam) (Poor to good), Ethoprop (Mocap) (Poor to good), and 1,3-Dichloropropene (Telone) (Poor in organic soils, excellent in non-organic soils). Telone is recognized as highly expensive. Township caps may limit Telone use.

Work Group Recommendations for Nematode Management -- Site Selection and Bed Preparation

RESEARCH	• Seasonal wetland plant species as hosts • Alternative fumigants and alternatives to fumigants
REGULATORY	• Getting registered, effective alternatives to fumigants • Ease restrictions on township caps
EDUCATION	• Educating policymakers on the full impacts of regulations that limit the use of certain fumigants • Educate public on actual risks of pesticide use

Weeds
Weeds are a problem because they can take nutrients, water and sunlight away from the intended crop. Some weeds such as dodder and nutsedge can physically damage the plant or tuber. However, potatoes are very fast growing, competitive plants that can be grown without the use of herbicides in some situations. Fields with vigorous stands can often shade out most weeds. Adverse conditions or pest problems however, can lead to slow growing plants that allow weeds to become established within a field.

The weed species that are of particular concern vary considerably because of the diverse growing areas and climates of these areas. Nettle, nutsedge, lambsquarters, and nightshade are the main weeds affecting potatoes in Kern County. In the Klamath Basin, the major weed pests of potatoes are pigweed, hairy nightshade and kochia. Other areas will have their own particular set of weeds that are troublesome.

Cultural Control: Crop rotation and cultivation are methods of cultural control that are routinely used. Crop rotations allow other methods of cultivation and herbicides to be used. This then prevents weeds that escape in the potato cropping system to be controlled in the alternative cropping system. Most growers cultivate before planting and again before

canopy closure to eliminate early season weeds. Potato plants are usually able to shade out any weeds that may emerge after the canopy closes.

Biological Control: none

Chemical Control: A variety of pre-plant and post-plant herbicides are used in potato production in California. In the Klamath Basin, because of the high organic soil, pre-emergent herbicides are less effective. The Klamath Basin is 100% dependant on post emergent materials. EPTC (Eptam) is the most commonly used material due to its ease of use and control activity on many weed species. Also, fumigation with Metam Sodium (Vapam) helps control weeds. Other materials include: Glyphosate (Roundup), Paraquat (Gramoxone Extra), Trifluralin (Treflan 5EC, etc.), Pendimethalin (Prowl), Sethoxydim (Poast), Rimsulfuron (Matrix) Metribuzin (Sencor 75DF, Lexone 75DF), and Metolachlor (Dual 8EC)

Work Group Recommendations Weed Management -- Site Selection and Bed Preparation

RESEARCH	• Control of purple and yellow nutsedge
REGULATORY	• Pacific Northwest labeling needs to extend into the Klamath Basin • Expand Sencor label to include Kern County • California Department of Pesticide Regulation accepting like studies from other states to harmonize California and the federal registrations
EDUCATION	• No recommendations

Vertebrates

Nothing is done at this phase.

Work Group Recommendations Vertebrates -- Site Selection and Bed Preparation

RESEARCH	• No recommendations
REGULATORY	• No recommendations
EDUCATION	• No recommendations

Planting

Planting time varies considerably from region to region depending on local climatic conditions and intended market use. In general, potatoes should not be planted when the soil is below 45°F (7°C) or above 70°F (21°C). At time of planting, soils should be moist but not excessively wet. In irrigated desert areas, it is common to pre-irrigate prior to planting. Planting in cold, wet or hot, dry soils increases the potential for seed piece decay. Within reasonable limits, the early establishment of a crop results in greater yield and dry matter potential. In regions where the growing season is longer than is required for full development of the varieties grown, planting dates are selected to provide the crop with the most favorable environment during the critical period of tuberization, proper maturity for the desired market, and economic yields.

The variety grown, fertilization program, availability of irrigation, soil type, and market outlet are major factors in determining the desired (between and within) row spacing of potatoes. Row widths generally range from 30-36 inches (76-91 cm), although both wider and narrower rows are used. Spacings within the row are influenced most by the intended market and the variety grown. Seed pieces of varieties with the tendency to set a small number of tubers and/or develop oversize tubers should be spaced at 7-9 inches (18-23 cm) apart within the row. Closer spacings may apply where irrigation is available or where moisture is not expected to be limiting. Varieties, which generally set a high number of tubers, should be spaced 11-14 inches (28-46 cm) apart in the row. The use of close-in row spacing may help reduce losses from hollow heart and growth cracks, and result in improved appearance and an increase in the number of marketable tubers.

The market outlet is a major determining factor in selecting the proper spacing. Potato processors who produce frozen French fried products desire large tubers, within limits, and often pay a premium for a high percentage of tubers over 10 ounces (284 g). Wide spacing enhances production of large tubers. Seed buyers, however, prefer tubers under 3 1/4 inches (8 cm) diameter or 10 ounces (284 g). Whole B-size tubers often demand a premium.

Cultural and Worker Activities

• Irrigation set up (post planting)
• Planting
• Fertilizing at planting
• Pesticide application in furrow
• Scouting for insects, weeds, and diseases
• Equipment sanitation

Diseases
Only certified, disease free seed is to be used.

Viruses
Cultural Control: Certified disease free seed tubers are planted and planting near alfalfa or clover is avoided. Good equipment sanitation.
Biological Control: none
Chemical Control: none

Bacterial Ring Rot (*Clavibacter michiganensis* subsp. *Sepedonicus*): The bacterial ring rot bacterium over winters in infected tubers. It does not live freely in the soil, but it can survive for long periods as a dried slime on harvesting and grading machinery, sacks, etc. A wound is required for infection and spread occurs most commonly when seed is cut.

Cultural Control: Certified disease free seed tubers are planted, rotating out of potatoes at least one year, and following strict sanitation procedures when cutting seed. Periodically disinfecting cutting tools in a 1% solution of calcium hypochlorite, and using whole-drop seeds to minimize spread. Cup-type planters spread the pathogen less than pick-type. Cleaning up volunteers and seed residue.
Biological Control: none
Chemical Control: none

Bacterial Soft Rot (*Erwinia carotovora* var. *carotovora, E. chrysanthemi*): Bacteria are present on all tubers and are associated with many kinds of plants. High soil moisture and high temperatures favor infections in the field. Other conducive factors include anaerobic conditions, enlarged lenticels, and invasion by other pathogens. Bacteria enter lenticels, growth cracks, or any injury. During and after harvest, soft rot is favored by immature tubers, adverse temperatures (pulp temperatures above 70°F at harvest), mechanical damage, and free water on tuber surfaces.

Cultural Control: Use high quality seed. Apply Gypsum at planting or side-dressed. Avoid excessive soil moisture before harvest to reduce lenticel infection; use clean water to wash potatoes; and avoid water films on tuber surfaces during storage. Post harvest curing and storage temperatures can be a critical component of soft rot management. Specific temperature recommendations vary depending on the level of decay evident at packing and the market destiny of the potatoes (i.e., processing, fresh market, or long-term storage).
Biological Control: none
Chemical Control: Fungicides do not directly affect these bacterial pathogens, but seed piece treatments with fungicides can reduce invasion by other fungi and therefore reduce opportunistic infection by *Erwinia* spp. Thiophanate Methyl/Mancozeb (Tops MZ) (fair), Fludioxonil (Maxxim MZ) (fair), Streptomycin (Agromycin) (fair).

Blackleg (*Erwinia carotovora* var. *atroseptica*)
Cultural Control: Use of pathogen-free tubers for seed. Seed tubers are warmed to about 55°F before planting. Good drainage is provided and over irrigate avoided. Cull piles, potato volunteers in rotation crops and adjacent fields are eliminated.
Biological Control: none
Chemical Control: Fungicides do not directly affect these bacterial pathogens, but seed piece treatments with fungicides can reduce invasion by other fungi and therefore reduce opportunistic infection by *Erwinia* spp. Thiophanate Methyl/Mancozeb (Tops MZ) (fair), Fludioxonil (Maxxim MZ) (fair), Streptomycin (Agromycin) (fair).

Calico (*Alfalfa Mosaic Virus*)**:** Alfalfa mosaic virus is transmitted by many species of aphids. Transmission of the virus is most likely to occur when aphids migrate into potato fields from nearby alfalfa or clover fields, the usual hosts for this virus. Infection often occurs on edges of fields located near alfalfa. Little or no secondary spread occurs within the potato field.

Cultural Control: Planting of certified seed tubers and avoiding planting near alfalfa or clover.
Biological Control: none
Chemical Control: none

Common Scab (*Streptomyces* spp.)
Cultural Control: Maintaining high soil moisture (80-90% of available water storage) during tuber initiation and the 6 to 8 weeks that follow reduces the severity of scab and usually controls the disease adequately. Other practices that help reduce the incidence of scab include crop rotation with green manure crops such as rye, millet, and oats; whereas, rotations with carrots, beets, spinach, turnip, and radish are not advisable. Avoid soil application of animal wastes, which favors scab development. Use certified seed tubers free from common scab. Variety selection is critical as some varieties are extremely susceptible. When applied before or at planting, some soil amendments such as sulfur, gypsum, and triple super phosphate, suppress common scab.
Biological Control: none
Chemical Control: none

Corky Ringspot (Tobacco rattle virus)
Cultural Control: Planting of certified clean seed tubers and avoiding fields with a history of corky ringspot.
Biological Control: none
Chemical Control: none

Early Blight (*Alternaria solani*)
Cultural Control: Planting of disease-free seed is critical. Adequately fertilizating and watering helps to avoid plant stress that can lead to early blight infection. Slower growing varieties may be less prone to becoming stressed.
Biological Control: none
Chemical Control: none

Fusarium Dry Rot and Seed Piece Decay (*Fusarium* spp.)
Cultural Control: Seed piece decay is reduced when seed pieces are planted under conditions that favor rapid suberization; *Fusarium* cannot infect cut surfaces after they are suberized. Seed tubers are warmed to 50^{o}F before cutting, and cutting and handling equipment is kept disinfected. Planting occurs when the soil temperature is at least 45^{o}F and when soil moisture is 60 to 80% of field capacity. If possible, irrigation before emergence is avoided.
Biological Control: none
Chemical Control: When planting conditions are likely to favor seed piece decay, cut seed pieces are treated with a fungicide. Pesticides used include Fludioxonil (Maxim) (poor to good), Thiophanate Methyl (Topsin M) (fair to good), and Mancozeb (Tops) (good).

Late Blight (*Phytophthora infestans*)
Cultural Control: The use of certified, disease free seed helps to reduce the chance of planting infected seed. Eliminating volunteers, cull piles, and alternate weed hosts help reduce early season inoculum levels in an area.
Biological Control: none
Chemical Control: Seed piece treatments that include Mancozeb (fair to good) and in-furrow treatments of Quadris (fair to good).

Leafroll
Cultural Control: Use of disease free seed pieces and varietal selection is important.
Biological Control: none
Chemical Control: Insecticides are appled from early to mid-season (move to later section) if aphids and potato leafroll virus are present. Late season vector control may offer no economic benefit if the potato variety is not susceptible to tuber net necrosis.

Pink Rot (*Phytophthora erythroseptica*)
Cultural Control: Planting under excessively wet conditions and letting fields become saturated for long periods of time are avoided.
Biological Control: none
Chemical Control: Pesticides used included mefenoxam (Ridomil Gold)

Powdery Scab (*Spongospora subterranea*)
Cultural Control: Planting of seed tubers affected by powdery scab and planting potatoes on sites with a history of the disease is avoided. Susceptibility varies among red, white and yellow varieties: with consideration given to planting less

sensitive varieties. Rotations out of potatoes for 3 or more years may be beneficial on some infested sites. Planting occurs in well-drained soils and over-irrigation is avoided.
Biological Control: none
Chemical Control: In fields with a history of powdery scab, preplant chemigation with Metam Sodium (Vapam) can reduce disease in a subsequent crop of potatoes.

Southern White Rot/Sclerotium Stem Rot (*Sclerotium rolfsii*)
Cultural Control: Early planted fields avoid the problem by being harvested before the warmer temperatures of early summer occur.
Biological Control: none
Chemical Control: Fields with a history of Southern white rot can benefit from fumigation with Metam-Sodium (Vapam).

Stem and Stolon Canker (*Rhizoctonia solani*)
Cultural Control: The use of certified, disease free seed reduces the amount of inoculum that is brought on the seed. Soil borne inoculum levels can be reduced by proper crop rotations. Tubers are harvested as soon as possible after vine kill to prevent infection of daughter tubers.
Biological Control: none
Chemical Control: Seed piece treatments can provide good control but are much less effective in regions where soil borne inoculum is present. Pesticides used include Thiophanate-methyl (Topsin) (poor to fair), Fludioxonil (Maxim)(fair to good) and Azoxystrobin (Quadris) (good).

Work Group Recommendations for Disease Management -- From Planting to Pre-emergence

RESEARCH	• In furrow fungicide for Rhizoctonia • Persistence of Rhizoctonia in soil (Klamath Basin) • Further research on controlling soil borne *Rhizoctonia* • Methods for expediting results of winter test plots to verify quality of seed • Efficacy of Blocker and Quadris for scab control • Evaluation of cover crops for various diseases
REGULATORY	• Pacific Northwest labeling needs to extend into the Klamath Basin • California Department of Pesticide Regulation accepting like studies from other states to harmonize California and the federal registrations • Better enforcement of existing quality control regulations for seed pieces • Improved methods for quality control of seed pieces
EDUCATION	• Importance of proper seed selection

Insects
Aphids: Green Peach (*Myzus persicae*) and **Potato Aphid** (*Macrosiphum euphorbiae*): These are the aphids of most concern and most common on potatoes. Aphids can cause damage to potatoes by directly feeding on the plants but more importantly they are vectors of several viruses. Controlling aphids is more important to growers of certified seed potatoes.

Cultural Control: Eliminating weeds along the field edges, nearby ditch banks, and roadsides helps keep early season aphid population low. Mustards and Malva are major weed hosts of aphids and should be especially targeted for control.
Biological Control: There are naturally occurring predators and parasites that feed on pests.
Chemical Control: Controlling aphids is usually not required in commercial potato fields but several applications of systemic insecticides such as Imidacloprid (Admire) (good), Thiamethoxam (Platinum) (good), Phorate (Thimet) (good). Admire may be required in fields grown for potato seed. Alternate chemistries for resistance management purposes. In the Klamath Basin, one or two treatments may be required on commercial fields with varieties sensitive to net necrosis caused by potato leaf roll virus.

Cutworms: Black cutworm (*Agrotis ipsilon*) and **Variegated cutworm** (*Peridroma saucia*)
Cultural Control: Weed control in and around the field before planting will reduce cutworm problems through reduction of early season host plants.
Biological Control: none
Chemical Control: none

Potato tuberworm (*Phthorimaea operculella*): Tuberworms are a problem in the warmer potato growing regions of California. Planting the seed deep and using varieties that set tubers deep help to prevent infections by the adult moths. Making large wide beds will help.

Cultural Control: Tubers are covered. Sprinkler irrigation seals the soil well as compared to furrow irrigation that allows cracks in the soil to form, exposing the tubers.
Biological Control: none
Chemical Control: Fumigation of infested seed pieces.

Wireworms: Pacific coast wireworm (*Limonius canus*), **Sugarbeet wireworm** (*L. californicus*) and **Dryland wireworm** (*Ctenicera pruinina*)
Cultural Control: none
Biological Control: none
Chemical Control: Ethoprop (Mocap) (good) and Imidacloprid (Admire) (poor to good depending on species), or Thiamethoxam (Platinum) (poor to good depending on species) can be used to reduce wireworm levels in the soil. The chemical material needs to be incorporated into the soil by tillage before planting.

Work Group Recommendations for Insect Management -- From Planting to Pre-emergence

RESEARCH	• Evaluate varietal differences in susceptibility to tuberworm damage
REGULATORY	• No recommendations
EDUCATION	• No recommendations

Nematodes
If fields have not been fumigated, nematodes might be a problem, and fields that have been fumigated might also experience problems depending on level of pest pressure.
Cultural Control: none
Biological Control: none
Chemical Control: Oxamyl (Vydate) (good), Ethoprop (Mocap) good on shallow nematodes missed by fumigation.

Work Group Recommendations for Nematode Management -- From Planting to Pre-emergence

RESEARCH	• Development of alternate methods for nematode control
REGULATORY	• No recommendations
EDUCATION	• No recommendations

Weeds
Nothing is done at this phase.

Pre-Emergence

During this phase, the seed potatoes will sprout and form the roots and underground stems (stolons), at the end of which the tubers will form. This production phase can be used to make, build or re-shape the beds, to cultivate for weed control, and to apply pre-emergence herbicides. Irrigation should be avoided except for incorporation of an herbicide. Some herbicides can/should be mechanically incorporated. Irrigation management to maintain soil moisture, cultivation, and application of herbicides are activities that growers engage in at the pre-emergence stage. Seed piece condition is monitored for the presence of rot and for emergence. “Dragging off” (knocking the hills down until almost flat) is sometimes used to hasten emergence and aid in weed control.

Cultural and Worker Activities

• Build or re-shape beds	• Irrigation
• Cultivation	• Pesticide applications
• Irrigation pipe setting	• Insect and Disease monitoring

Diseases
Nothing is done at this phase.

Insects

Cutworms: Black cutworm (*Agrotis ipsilon*) and **Variegated cutworm** (*Peridroma saucia*): Cutworms may cut off the stems of young plants during stand establishment. Later in the season they feed on foliage. Tubers that are exposed on the soil, or by cracks, or are set very shallow may be damaged. Cutworm damage to tubers appears as a gouged out cavity.

Cultural Control: Weed control in and around the field before planting will reduce cutworm problems through reduction of early season host plants. The field is monitored early in the season to detect cut plants and foliar feeding. Later in the season, plants are inspected for foliage damage. The beds and furrows are also inspected for larvae along with inspecting the shallow set and exposed tubers for damage.
Biological Control: none
Chemical Control: Permethrin (Pounce) (good to excellent), Esfenvalerate (Asana) (good to excellent).

Leafminer: Heavy pocket infestations would require chemical treatments in late summer/fall and in desert areas.
Cultural Control: The discing of any host potato crops in the immediate area.
Biological Control: none
Chemical Control: Agrimek (fair-good), Success (fair-good), Monitor (good but harmful to beneficials)

Potato psyllid (*Bactericerca* (*Paratrioza*) *cockerelli*)
Cultural Control: none
Biological Control: none
Chemical Control: Thionex (good-excellent), Asana (fair-good), Leverage (good), Monitor (good but harmful to beneficials)

Work Group Recommendations for Insect Management -- Pre-Emergence

RESEARCH	• No recommendations
REGULATORY	• No recommendations
EDUCATION	• No recommendations

Nematodes

If fields have not been fumigated, nematodes might be a problem, and fields that have been fumigated might also experience problems depending on level of pest pressure.

Cultural Control: none
Biological Control: none
Chemical Control: Oxamyl (Vydate) (good)

Work Group Recommendations for Nematode Management -- Pre-Emergence

RESEARCH	• No recommendations
REGULATORY	• No recommendations
EDUCATION	• No recommendations

Weeds

Nettle, nutsedge, lambsquarters, and nightshade are the main weeds affecting potatoes in Kern County. In the Klamath Basin, the major weed pests of potatoes are pigweed, hairy nightshade and kochia. Other areas will have their own particular set of weeds that are troublesome.

Cultural Control: Crop rotation and cultivation are methods of cultural control that are routinely used. Breaking down the beds and rebuilding gradually is an alternative to herbicides, but is costly and fuel intensive. Crop rotations allow other methods of cultivation and herbicides to be used. This prevents weeds that escape in the potato cropping system to be controlled in the alternative cropping system. Most growers cultivate before planting and again before canopy closure to eliminate early season weeds. Potato plants are usually able to shade out any weeds that may emerge after the canopy closes (5).
Chemical Control: A variety of pre-plant and post-plant herbicides are used in potato production in California for treatment of weeds. EPTC (Eptam) is the most commonly used material due to its ease of use and control activity on

many weed species. Other materials include: Glyphosate (Roundup), Paraquat (Gramoxone Extra), Trifluralin (Treflan 5EC, etc.), Pendimethalin (Prowl), Sethoxydim (Poast), Rimsulfuron (Matrix), and Metolachlor (Dual 8EC). Additional options for Tulelake and other regions: Metribuzin (Sencor 75DF, Lexone 75DF).

Work Group Recommendations for Weed Management -- Pre-Emergence

RESEARCH	• Pre-emergent herbicides (Klamath Basin)
REGULATORY	• Air label for Matrix • Expansion of federal labels to include California
EDUCATION	• No recommendations

Vertebrates

Voles (*Microtus* spp.): Perimeter treatments with bait. Zinc-phosphide (good), Chlorophacinone (Rozol) (good), Diphacinone (Ramik) (good)

Work Group Recommendations Vertebrate Management -- Pre-Emergence

RESEARCH	• Effective non chemical control for wild life critical habitats and organic growers
REGULATORY	• No recommendations
EDUCATION	• No recommendations

Post-Emergence

Further mechanical operations on top of the bed should be ceased during this critical phase to avoid breaking the main sprout, which will reduce vigor and yield and make the plant more susceptible to pathogens. During this phase, however, cultivation to throw more soil onto the top of the beds, even covering emerged plants, will create more internodes underground, thus more stolon formation and more opportunity for tuber set. Fields in the southern half of California commonly are only cultivated once, to form the large beds, after planting. The fewer passes through the field with heavy equipment the less soil compaction that will occur and the less energy that is used.

Hilling operations in sprinkler-irrigated fields are performed when plants are emerging and hilling is completed before plants are too large as to minimize severe root pruning. Discs, rolling cultivators, hilling listers, or implements with winged cultivator teeth are used.

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

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

Cultural and Worker Activities

• Irrigation	• Cultivation
• Fertilize	• Petiole analysis for nutrition
• Pest scouting	• Pesticide applications

Diseases

Chemical control requires the use of a preventive program in which the all green tissue is thoroughly covered with a fungicide. Fungicide applications may be required on a 7 to 10 day schedule to insure that new foliage is covered. Under cool, rainy conditions the spray intervals may need to be shortened. Pesticides used include Mancozeb (Dithane, Manzate, Penncozeb), Maneb, Cymoxanil (Curzate).

Viruses - on occasion treatments occur for the vectors.

Corky Ringspot (Tobacco rattle virus)
Cultural Control: none
Biological Control: none
Chemical Control: Oxamyl (Vydate) (good) for nematode control

Early Blight (*Alternaria solani*)
Cultural Control: Adequate fertilization and watering helps to avoid plant stress that can lead to early blight infection. Slower growing varieties may be less prone to becoming stressed.
Biological Control: none
Chemical Control: Early season infections are rare but if occur may require several applications for continued protection. Thorough coverage is needed for crop protection. Pesticides used include Chlorothalonil (Bravo)(good), Mancozeb (Dithane, Manzate, Penncozeb) (good), Maneb (good), Iprodione (Rovral) (good), Azoxystrobin (Quadris) (good), and Pyraclostrobin (Headline) (good), and Boscalid (Endura) (good). Need to alternate chemistries for resistance management.

Late Blight (*Phytophthora infestans*)
Cultural Control: Disease forecasting models are utilized along with the scouting and monitoring for disease incidence locally and regionally. Proper irrigation management including avoiding extended periods of leaf wetness use of tail water for irrigation. Eliminating volunteers, cull piles, and alternate weed hosts continues to help reduce early season inoculum levels in an area. Flaming to prevent spores spreading to the rest of the field can contain small outbreaks in a field and is organically acceptable.
Biological Control: none
Chemical Control: Chemical control requires the use of a preventive program in which the all green tissue is thoroughly covered with a fungicide. Fungicide applications may be required on a 7 to 10 day schedule to insure that new foliage is covered. Under cool, rainy conditions the spray intervals may need to be shortened. Pesticides used as protectants include, Mancozeb (Dithane, Manzate, Penncozeb), Maneb (Various products) (good), Chlorothanonil (Bravo) (good). Pesticides with some curative effects include Ethylene (Curzate) (good), Dimethomorph (Acrobat) (good), Fenamidone (Reason, Tanos) (good), Azoxystrobin (Quadris) (fair to good).

Leafroll
Cultural Control: none
Biological Control: none
Chemical Control: Chemical control of potato leafroll virus is aimed at controlling aphids in order to reduce spread of the virus within a field. Insecticides are applied from early to mid-season if aphids and potato leafroll virus are present. Late season vector control may offer no economic benefit if the potato variety is not susceptible to tuber net necrosis.

Leak (Water Rot) (*Pythium* spp.)
Cultural Control: Over watering is avoided, especially as tubers reach maturity.
Biological Control: none
Chemical Control: The first of two fungicide applications may be required. Pesticides used include Mefenoxam (Ridomil Gold MZ) (fair) and Mefenoxam/Chlorothalonil (Ridomil Gold, Bravo) (fair).

Pink Rot (*Phytophthora erythroseptica*)
Cultural Control: Letting fields becoming saturated for long periods of time is avoided.
Biological Control: none
Chemical Control: The first of two fungicide applications may be required. Pesticides used include Mefenoxam (Ridomil Gold MZ) (fair) and Mefenoxam/Chlorothalonil (Ridomil Gold, Bravo) (fair).

Powdery Scab (*Spongospora subterranean*)
Cultural Control: Over-irrigation is avoided.
Biological Control: none

Chemical Control: none

Stem and Stolon Canker (*Rhizoctonia solani*)
Cultural Control: Over-irrigation is avoided. .
Biological Control: none
Chemical Control: Fungicide applications with Azoxystrobin (Quadris) (good).

White Mold (*Sclerotinia sclerotiorum*)
Cultural Control: Excessive amounts of water and fertilizers produce overly dense canopies, which should be avoided.
Biological Control: none
Chemical Control: Effective control with chemicals is difficult because the fungus is at the soil line and appears after the canopy closes. Treatments are helpful when they can reach the area of infection. Pesticides used include Iprodione (Rovral) (poor-fair), Boscalid (Endura) (good)

Work Group Recommendations for Disease Management -- Post-Emergence

RESEARCH	• Application timing and technique to control white mold • Efficacy of materials on white mold • Efficacy of Fenamidone (Reason) on pink rot. • Development of fungicides for late blight • Regionalized validation of and adjustments to weather forecasting models
REGULATORY	• Registration of Fluazinam (Omega) registration and other new materials • Expedite registration of fungicides of late blight
EDUCATION	• Educate growers on use of Endura • Use of weather forecasting models (particularly for late blight)

Insects

Aphids: Green Peach (*Myzus persicae*) and **Potato Aphid** (*Macrosiphum euborbiae*): Monitoring for aphid appearance and treatment as necessary.
Cultural Control: none
Biological Control: none
Chemical Control: Controlling aphids is usually not required in commercial potato fields unless virus spread is suspected. Applications of Methamidophos (Monitor) (excellent), Endosulfan (Thionex, Thiodan) (good), Acetamiprid (Assail) (good), Thiamethoxam (Actara) (good) and Imidacloprid (Provado) (fair-good) generally only required in fields grown for potato seed. One or two treatments may be required on commercial fields with varieties sensitive to net necrosis caused by potato leaf roll virus.

Cutworms: Black cutworm, (*Agrotis ipsilon*) and **Variegated cutworm** (*Peridroma saucia*)
Cultural Control: none
Biological Control: none
Chemical Control: Esfenvalerate (Asana) (excellent), Permethrin (Pounce) (excellent), Methamidophos (Monitor) (fair), carbaryl bait (Sevin) (excellent).

Potato tuberworm (*Phthorimaea operculella*)
Cultural Control: Tubers are covered. Sprinkler irrigation seals the soil well as compared to furrow irrigation that allows cracks in the soil to form, exposing the tubers. Pheromone traps are used for monitoring flights to determine thresholds and time pesticide applications.
Biological Control: none
Chemical Control: One or more applications of pesticides used include Methomyl (Lannate LV) (poor), Methamidophos (Monitor) (excellent) and Esfenvalerate (Asana) (fair to good). Pesticide applications that target adults are most effective when applied in the early evening or at night.

Work Group Recommendations for Insect Management -- Post-Emergence

RESEARCH	• Development of area wide monitoring program for tuber moth • Revised economic thresholds • Evaluation of new reduced-risk insecticides
REGULATORY	• Expedition of new product registrations
EDUCATION	• No recommendations

Nematodes

If fields have not been fumigated, nematodes might be a problem, and fields that have been fumigated might also experience problems depending on level of pest pressure.
Cultural Control: none
Biological Control: none
Chemical Control: Oxamyl (Vydate) (good)

Work Group Recommendations for Nematode Management -- Post-Emergence

RESEARCH	• Timing of vydate application
REGULATORY	No recommendations
EDUCATION	• Timing of vydate application

Weeds

Cultural Control: Crop rotation and cultivation are methods of cultural control that are routinely used. Crop rotations allow other methods of cultivation and herbicides to be used. This then prevents weeds that escape in the potato cropping system to be controlled in the alternative cropping system. Most growers cultivate before planting and again before canopy closure to eliminate early season weeds. Potato plants are usually able to shade out any weeds that may emerge after the canopy closes. Organic growers may use hand weeding.

Chemical Control: A variety of pre-plant and post-plant herbicides are used in potato production in California for treatment of emergent weeds. EPTC (Eptam) is the most commonly used material due to its ease of use and control activity on many weed species. Other materials include: Glyphosate (Roundup), Paraquat (Gramoxone Extra), Trifluralin (Treflan 5EC, etc.), Pendimethalin (Prowl), Sethoxydim (Poast), Rimsulfuron (Matrix), and Metolachlor (Dual 8EC). Additional option for Tulelake and other regions: Metribuzin (Sencor 75DF, Lexone 75DF).

Work Group Recommendations for Weed Management -- Post-Emergence

RESEARCH	• Screen herbicides for nightshade and nutsedge control
REGULATORY	• No recommendations
EDUCATION	• No recommendations

Vertebrates

Voles (*Microtus* spp.): Perimeter treatments with bait. Zinc-phosphide (good), Chlorophacinone (Rozol) (good), Diphacinone (Ramik) (good)

Work Group Recommendations Vertebrate Management -- Post-Emergence

RESEARCH	• No recommendations
REGULATORY	• No recommendations
EDUCATION	• No recommendations

Row Closure - Bulking

By the time the "rows have closed", i.e. plants from adjoining rows are touching each other, all mechanical operations

should have ceased, except for ground applications of fungicides. This is a critical time for the potential of foliar diseases because air circulation is minimal, allowing free moisture to remain on the leaf surface. Irrigation at night and early morning will enable drying of the leaves in the afternoon and early evening, thus preventing the potential for developing diseases. Fertilizer applications through the irrigation are common, and usually necessary, for maximum growth and health during this phase.

Cultural and Worker Activities

• Irrigation	• Cultivation
• Fertilize	• Petiole analysis for nutrition
• Pest scouting is much more critical at this phase	• Pesticide applications

Diseases

Chemical control requires the use of a preventive program in which the all green tissue is thoroughly covered with a fungicide. Fungicide applications may be required on a 7 to 10 day schedule to insure that new foliage is covered. Under cool, rainy conditions the spray intervals may need to be shortened. Pesticides used include Mancozeb (Dithane, Manzate, Penncozeb), Maneb, Cymoxanil (Curzate).
Previously described measures are continued.

Viruses

Due to increased foliage the need for vector control is more important now.
Cultural Control: none
Biological Control: none
Chemical Control: Fields are monitored for aphids to determine if treatments are needed as previously described.

Bacterial Soft Rot (*Erwinia carotovora* var. *carotovora, E. chrysanthemi*): Bacteria are present on all tubers and are associated with many kinds of plants. High soil moisture and high temperatures favor infections in the field. Other conducive factors include anaerobic conditions, enlarged lenticels, and invasion by other pathogens. Bacteria enter lenticels, growth cracks, or any injury. During and after harvest, soft rot is favored by immature tubers, adverse temperatures (pulp temperatures above 70°F at harvest), mechanical damage, and free water on tuber surfaces.

Cultural Control: Split applications of water-soluble calcium applied at 100-200 lb/acre during bulking have been shown to reduce infectionand severity of soft rot. This is the only known treatment at this time and is an inadequate control measure. Excessive soil moisture is avoided before harvest to reduce lenticel infection; potatoes are washed with clean water; and water films on tuber surfaces during storage are avoided. Post harvest curing and storage temperatures can be a critical component of soft rot management. Specific temperature recommendations vary depending on the level of decay evident at packing and the market destination of the potatoes (i.e., processing, fresh market, or long-term storage).
Biological Control: none
Chemical Control: none

Blackleg (*Erwinia carotovora* var. *atroseptica*)
Cultural Control: Providing good drainage and not over irrigating. Cull piles and potato volunteers are eliminated in rotation crops and adjacent fields. Damage to foliage is avoided.
Biological Control: none
Chemical Control: none

Common Scab (*Streptomyces* spp.)
Cultural Control: none
Biological Control: none
Chemical Control: Applications of sulfur-based soil amendments.

Corky Ringspot (Tobacco rattle virus)
Cultural Control: none
Biological Control: none
Chemical Control: Vydate (good) through chemigation is applied.

Early Blight (*Alternaria solani*)
Cultural Control: Adequate fertilization and watering helps to avoid plant stress that can lead to early blight infection. Slower growing varieties may be less prone to becoming stressed.

Biological Control: none
Chemical Control: Early season infections are rare and may require several applications for continued protection. Thorough coverage is needed for crop protection. Pesticides used include Chlorothalonil (Bravo) (good), Mancozeb (Dithane, Manzate, Penncozeb) (good), Maneb (good), Iprodione (Rovral) (good), Azoxystrobin (Quadris) (good). Need to alternate chemistries for resistance management.

Late Blight (*Phytophthora infestans*): If there is Late blight in the area, aggressive treatment needs to occur. New strains of the fungus have developed that are resistant to Mefenoxam (Ridomil Gold). The new strains are also more aggressive and able to cause infection over a greater environmental range than previous strains.
Cultural Control: Irrigating at night prevents overlap of dew and irrigation moisture.
Biological Control: none
Chemical Control: Chemical control requires the use of a preventive program in which the all green tissue is thoroughly covered with a fungicide. Fungicide applications will be required on a 7 to 10 day schedule to insure that new foliage is covered. Under cool, rainy conditions the spray intervals may need to be shortened. Pesticides used in combination which work well as protectants include, Mancozeb (Dithane, Manzate, Penncozeb), Maneb, Propamocarb (Tattoo), Ethylene (Curzate), Dimethomorph (Acrobat), Bravo.

Leafroll
Cultural Control: none
Biological Control: none
Chemical Control: Chemical control of potato leafroll virus is aimed at controlling aphids in order to reduce spread of the virus within a field. Insecticides are applied from early to mid-season if aphids and potato leafroll virus are present. Late season vector control may offer no economic benefit if the potato variety is not susceptible to tuber net necrosis.

Leak (Water Rot) (*Pythium* spp.)
Cultural Control: Over watering is avoided, especially as tubers reach maturity. Infected tubers are allowed to decay completely before harvesting to avoid spreading in storage or transit.
Biological Control: none
Chemical Control: If needed, the second of two applications of fungicides including Mefenoxam (Ridomil Gold MZ) (fair) and Mefenoxam/Chlorothalonil (Ridomil Gold, Bravo)(fair).

Pink Rot (*Phytophthora erythroseptica*)
Cultural Control: Letting fields become saturated for long periods of time is avoided.
Biological Control: none
Chemical Control: If needed, the second of two applications of fungicides including Mefenoxam (Ridomil Gold MZ) (fair) and Mefenoxam/Chlorothalonil (Ridomil Gold, Bravo)(fair).

Powdery Scab (*Spongospora subterranea*)
Cultural Control: Over-irrigation is avoided.
Biological Control: none
Chemical Control: none

Southern White Rot/Sclerotium Stem Rot (*Sclerotium rolfsii*)
Cultural Control: Ammonium bicarbonate applications late in the season may help prevent tuber infection.
Biological Control: none
Chemical Control: Applications of Azoxystrobin (Quadris) (fair to good, better when used in combination with ammonium bicarbonate)

White Mold (*Sclerotinia sclerotiorum*): Scout for apothecia and treat as necessary.
Cultural Control: Excessive amounts of water and fertilizers produce overly dense canopies, which should be avoided.
Biological Control: none
Chemical Control: Effective control with chemicals is difficult because the fungus is at the soil line and appears after the canopy closes. Treatments are helpful when they can reach the area of infection. Pesticides used include Iprodione (Rovral) (poor-fair), Boscalid (Endura) (good), Thiophanate Methyl (Topsin-M) (poor-fair).

Work Group Recommendations for Disease Management Row Closure -- Bulking

RESEARCH	• Application timing and technique to control white mold • Efficacy of materials on white mold

	• Efficacy of Fenamidone (Reason) on pink rot • Localized validation of weather forecasting models
REGULATORY	• Registration of Fluazinam (Omega) and other new materials • Expansion of regulations to better include quality control of seed pieces from bacterial and fungal diseases, including better reporting of bacterial and fungal inspection results • More stringent and better enforcement of seed piece quality control by certification agencies, particularly
EDUCATION	• Educate growers on use of Boscalid (Endura) • Educate growers on destruction of infested fields (plowing down)

Insects

Controls are same as previous phase only more aggressive due to greater canopy and warmer temperatures.

Potato tuberworm (*Phthorimaea operculella*)
Cultural Control: Pheromone traps are used to monitor adult moths. Treatment levels have been developed for Kern County and Salinas Valley based on the number of moths trapped per night (M/T/N). It is recommended that Kern County Region growers treat at 15-20 M/T/N while Salinas Valley growers treat at 40 M/T/N. Klamath Basin has no current population but pest is spreading through the Pacific Northwest and growers are very concerned.
Biological Control: none
Chemical Control: Pesticides used include Methomyl (Lannate LV), Methamidophos (Monitor) and Esfenvalerate (Asana).

Work Group Recommendations for Insect Management Row Closure – Bulking

RESEARCH	• Development of area wide monitoring program for tuber moth • Revised economic thresholds • Evaluation of new reduced-risk insecticides
REGULATORY	• Expedition of new product registrations
EDUCATION	• No recommendations

Nematodes

If fields have not been fumigated, nematodes might be a problem, and fields that have been fumigated might also experience problems depending on level of pest pressure.

Cultural Control: none
Biological Control: none
Chemical Control: Oxamyl (Vydate) (good) 7-day PHI check plant back restrictions that may prohibit use for rotational crops.

Work Group Recommendations for Nematode Management Row Closure – Bulking

RESEARCH	• Determining if Vydate could be effective on nematodes used mid-late season
REGULATORY	• No recommendations
EDUCATION	• Publication of nematode degree-days

Weeds

Nothing is done at this phase on current crop; scouting for weed populations on future years ground. In the Delta Basin, treatments with Sethoxydim (Poast) (good) are used for grassy weeds.

Work Group Recommendations Weed Management Row Closure – Bulking

RESEARCH	• No recommendations
REGULATORY	• No recommendations
EDUCATION	• No recommendations

Vertebrates
Voles (*Microtus* spp.): Perimeter treatments with bait. Zinc-phosphide (good), Chlorophacinone (Rozol) (good), Diphacinone (Ramik) (good)

Work Group Recommendations Vertebrate Management Row Closure – Bulking

RESEARCH	• No recommendations
REGULATORY	• No recommendations
EDUCATION	• No recommendations

Plant Growth Regulators - Approximately 80% of table stock in the Klamath Basin and 10% in the Kern Region are treated for sprouting and tuber shape; not used on seed.
Cultural Control: none
Biological Control: none
Chemical Control: Maleic Hydrazide, Potassium Salt (MH-30)

Vine kill

Vine killing does not necessarily result in improved tuber quality but does help achieve a desired "skin set" and may help reduce bruising. Internal quality must be "built in" to the crop at harvest time through the proper production techniques. Timely vine killing allows the skins of tubers to toughen so they can be harvested with a minimum of skinning and bruises. Bruised and skinned areas detract from the potatoes' appearance, an important quality parameter for those sold on the fresh market. They also increase waste and costs when used for processing. There are several other reasons for killing vines before harvest. Harvesting is easier when vines are dead. Under some conditions, vine killing is necessary to control tuber size. This can be especially important for growers of seed potatoes. Early vine killing is often used for the seed crop to prevent the spread of leaf roll and other virus diseases when a late season infestation of aphids occurs. Vines are difficult to kill when soil moisture is high or plants are large, green and vigorously growing. It takes more time for these plants to die than vines that are naturally maturing. Cool and cloudy weather conditions also retard vine death. Vines need to be killed either by frost or artificially, two to three weeks before harvest depending upon variety, conditions of growth, and time of year. Varieties that have large vines and are late maturing may require even more time.

The three general methods used for vine killing are 1) mechanical, 2) chemical (see appendix 10), and 3) combinations of the two. Flail beaters and rotary choppers are popular mechanical methods. Machines should be adjusted to avoid disturbing the soil so that tubers will not be exposed to sunlight, frost, or mechanical damage. Rollers made of used truck tires over a cylinder are used to crush stems and mash down vines. This hastens vine and tuber maturity and improves coverage of chemical vine killing sprays. Propane gas or oil flames are used in some areas to burn vines. Regulations concerning the influence of smoke on environmental quality, however, have reduced the use of this method. Vine burning has some disease control aspects that may be of significant benefit. Because conditions vary from area to area, local recommendations for methods and rates and timing of materials must be understood and followed.

Practicing the following can increase effectiveness of vine killing:

- Roll to bend tops before spraying. This allows more spray to reach the plant stems and results in improved vine kill. Rolling the vines may close cracks and thus reduce the number of green (sunburned) tubers.
- If a rota beater is used, have enough clearance between the flails and the top of the potato row to avoid uncovering and/or damaging tubers or disturbing the soil.
- Do not apply vine-killing chemicals during cool, damp, or extremely hot, dry weather.
- Under some conditions, split applications of chemical vine killers may be more effective than a single application. Where the labeled use will permit, use less than the full application rate, followed by a second application several days later. Rolling before spraying may eliminate the necessity for the second application if weather is warm.
- Use spray adjuvants that are recommended.

Cultural and Worker Activities

• Chopping and/or spraying

Diseases

Bacterial Soft Rot (*Erwinia carotovora* var. *carotovora, E. chrysanthemi*)
Cultural Control: Scheduling of shut down of irrigation so dry down is sufficient.
Biological Control: none
Chemical Control: none

Blackleg (*Erwinia carotovora* var. *atroseptica*)
Cultural Control: Scheduling of shut down of irrigation so dry down is sufficient.
Biological Control: none
Chemical Control: none

Early Blight (*Alternaria solani*): If huge inoculum builds up prior to vine kill, it can encourage tuber infection
Cultural Control: none
Biological Control: none
Chemical Control: none

Fusarium Dry Rot and Seed Piece Decay (*Fusarium* spp.)
Cultural Control: Ample time for skin set is allowed to prevent shatter bruise, thereby not creating an entry place for Fusarium.
Biological Control: none
Chemical Control: none

Late Blight (*Phytophthora infestans*)
Cultural Control: Vines are desiccated and the beds rolled to block the soil cracks. Flaming to prevent spores spreading to the rest of the field can contain small outbreaks in a field.
Biological Control: none
Chemical Control: Late blight fungicides are applied.

Leak (Water Rot) (*Pythium* spp.)
Cultural Control: Scheduling of shut down of irrigation so dry down is sufficient.
Biological Control: none
Chemical Control: none

Pink Rot (*Phytophthora erythroseptica*)
Cultural Control: Scheduling of shut down of irrigation so dry down is sufficient.
Biological Control: none
Chemical Control: none

Southern White Rot/Sclerotium Stem Rot (*Sclerotium rolfsii*)
Cultural Control: Amendments with ammonium bicarbonate help by killing the mycelium in the soil. Ammonium bicarbonate applications late in the season may help prevent tuber infection.
Biological Control: none
Chemical Control:) none

Work Group Recommendations for Disease Management -- Vine Kill

RESEARCH	• Efficacy of Reason for leak and pink rot
REGULATORY	• Registration of Fluazinam (Omega) and other new materials
EDUCATION	• Educate growers on use of Boscalid (Endura)

Insects

Potato tuberworm (*Phthorimaea operculella*)
Cultural Control: Hills are rolled to avoid soil cracking and flights are monitored.
Biological Control: none
Chemical Control: Esfenvalerate (Asana) (good on adults).

Work Group Recommendations for Insect Management -- Vine Kill

RESEARCH	• Research on tuber moth presence (pheromone traps)
REGULATORY	• No recommendations
EDUCATION	• No recommendations

Nematodes

If fields have not been fumigated, nematodes might be a problem. Fields that appear to have a root knot problem need to be harvested early.

Work Group Recommendations for Nematode Management -- Vine Kill

RESEARCH	• No recommendations
REGULATORY	• No recommendations
EDUCATION	• No recommendations

Weeds

Post desiccation control of weeds both for harvest operation and reduced seed spreading for future year.

Work Group Recommendations Weed Management -- Vine Kill

RESEARCH	• No recommendations
REGULATORY	• No recommendations
EDUCATION	• No recommendations

Vertebrates

Voles (*Microtus* spp.): Perimeter treatments with bait. Zinc-phosphide (good), Chlorophacinone (Rozol) (good), Diphacinone (Ramik) (good)

Work Group Recommendations Vertebrates -- Vine Kill

RESEARCH	• No recommendations
REGULATORY	• No recommendations
EDUCATION	• No recommendations

Harvest

Windrowing the tubers onto the soil surface can increase the exposure of the tubers to air, thus enhancing skin set, and increase the efficiency of the harvesting machines. In some cases, a few hours on top of the ground will convert immature tubers to mature tubers. If the tubers are already mature, this step will not be necessary. Harvesting practices should be employed that minimize cuts, bruises and abrasions. These include moist soil, modern harvesters, proper chain speeds, minimum drop heights into the trucks and from the trucks, and padded surfaces anywhere a tuber may encounter metal or wood. Even microscopic cracks are potential entries for pathogens.

Chemical Control: (Klamath Basin) In areas susceptible to *Fusarium* application of Mertec is recommended as potatoes go into storage.

Leak (Water Rot) (*Pythium* spp.)
Cultural Control: Over watering is avoided, especially as tubers reach maturity. Infected tubers areallowed to decay completely before harvesting to avoid spread in storage or transit.
Biological Control: none
Chemical Control: none

Post-harvest

The practices employed to ensure minimal bruising and damage at harvest should be continued postharvest. This includes packing shed, storage, and any form of movement. If sorted and packed immediately following harvest, the tubers should be refrigerated as soon as possible thereafter at 40-45^{o} F. Washing is a common practice to remove soil and enhance the tuber visual quality. Wash water is also an efficient carrier of bacterial and fungal organisms. Thus, some type of bactericide is commonly included in the wash water. Complete drying is essential to prevent decay. Sponge rollers, used to assist in drying, can also be a reservoir for pathogens, thus sanitizing them regularly is critical.

Tubers that are moved from the field to storage need to be cured before the temperature is reduced. Curing occurs most rapidly at 65 – 75^{o} F and 95-99% RH. The natural tuber heat from the field will easily create the warm temperature requirements. The storage/tuber temperatures should be slowly lowered over a few days to the desired temperature (approx. 40-42^{o} F for fresh, 55^{o} F for chipping stock). Removal from storage must be done with the same precautions and used in placing the tubers into storage. Fungicides may be placed onto the tubers either during the packing operation or as they are placed into storage. Sprout inhibitors may be placed in storages after the curing process is complete.

Post Harvest Disease Issues

Post harvest losses may be due to physiological disorders (due to storage and handling) or diseases. Diseases impacting potato quality after harvest include Pink Rot, Fusarium, Late Blight, Soft Rot, Early Blight and Silver Scurf.

Cultural Control: Monitoring for problems and areas of rot and ventilation is increased and humidity decreased. Air is run right through the bad spot and in extreme situations potatoes must be run. Potato lots known to have the potential for rot are moved out.
Biological Control: none
Chemical Control: Purigene (chlorine based material) is misted through the air system for all rots. CIPC (G) for sprout control. Cinnamon oil and clove oil (approved for organic). 1,4 Sight (DMNN).

References

Crop Profile for California Potato Production (draft form)

University of California Pest Management Guidelines
http://www.ipm.ucdavis.edu/PMG/selectnewpest.potatoes.html

Pest Management Strategic Plan for Pacific Northwest Potato Production
http://pestdata.ncsu.edu/pmsp/pdf/PNWPotatoPMSP.pdf

University of California Vegetable Research and Information Center
http://vric.ucdavis.edu/usesites/ressite.htm

California Department of Pesticide Regulation - Pesticide Use Reports
http://www.cdpr.ca.gov/docs/pur/purmain.htm

National Ag Statistics
http://www.usda.gov/nass/

California Ag Statistics Service
http://www.cdfa.ca.gov/publications.htm

Commercial Potato Production In North America
http://cropandsoil.oregonstate.edu/classes/CSS322/Cppina.htm

Appendices

Appendix 1: Cultural Practices and IPM Calendars for California Potatoes

Klamath Basin Production

Includes: Modoc and Siskiyou counties

Cultural Practice	J	F	M	A	M	J	J	A	S	O	N	D
Bed Prep												
Fumigation												
Planting												
Fertilization												
Cultivation												
Vine Kill												
Irrigation												
Harvest												
IPM Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Soil Sampling												
Irrigation Scheduling												
Petiole Sampling												
Insecticides												
Preemerg. Herbicides												
Contact Herbicides												
Weed Scouting												
Hand Weeding (organic)												
Fungicides												
Insect Scouting												
Disease Scouting												

Appendix 1, continued: Cultural Practices and IPM Calendars for California Potatoes

Delta Basin Production

Includes: San Joaquin County

Cultural Practice	J	F	M	A	M	J	J	A	S	O	N	D
Bed Prep												
Fumigation												
Planting												
Fertilization												
Cultivation												
Vine Kill												
Irrigation												
Harvest												
IPM Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Soil Sampling												
Irrigation Scheduling												
Petiole Sampling												
Insecticides												
Preemerg. Herbicides												
Contact Herbicides												
Hand Weeding (organic)												
Fungicides												
Insect Scouting												
Disease Scouting												

Appendix 1, continued: Cultural Practices and IPM Calendars for California Potatoes

Kern Region Production, Spring

Includes: Kern and Los Angeles counties

Spring

Cultural Practice	J	F	M	A	M	J	J	A	S	O	N	D
Bed Prep												
Fumigation												
Planting												
Fertilization												
Cultivation												
Vine Kill												
Irrigation												
Harvest												
IPM Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Soil Sampling												
Irrigation Scheduling												
Petiole Sampling												
Insecticides												
Preemergence Herbicides												
Contact Herbicides												
Hand Weeding (organic)												
Fungicides												
Insect Scouting												
Disease Scouting												

Appendix 1, continued: Cultural Practices and IPM Calendars for California Potatoes

Kern County Region Production, Fall

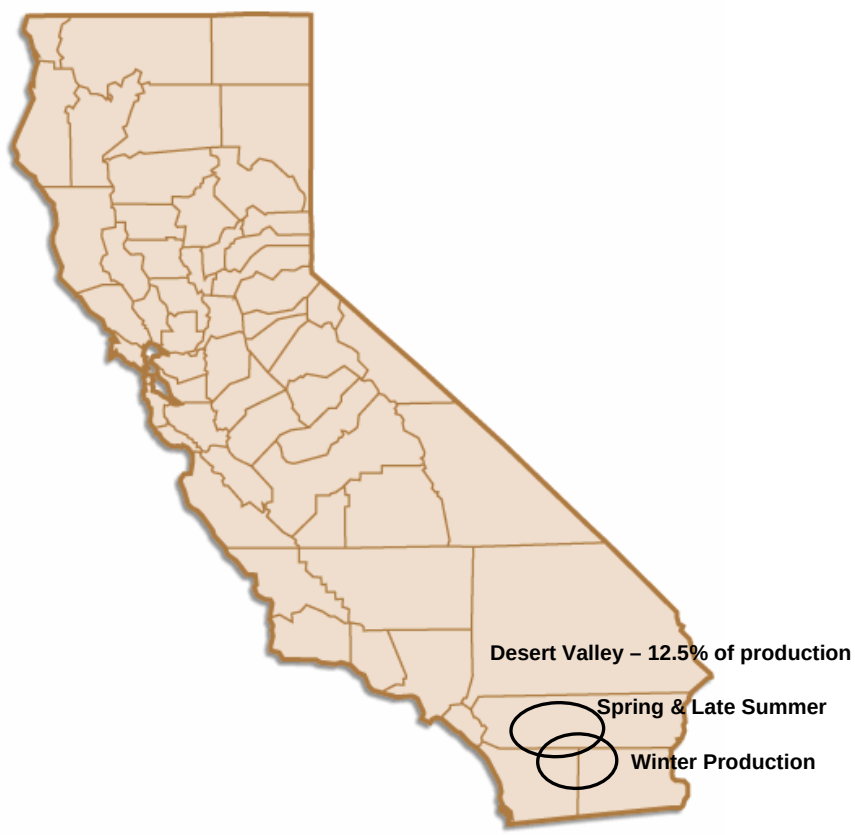
Includes: Kern and Los Angeles counties

Fall

Cultural Practice	J	F	M	A	M	J	J	A	S	O	N	D
Bed Prep												
Fumigation												
Planting												
Fertilization												
Cultivation												
Vine Kill												
Irrigation												
Harvest												
IPM Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Soil Sampling												
Irrigation Scheduling												
Petiole Sampling												
Insecticides												
Preemergence Herbicides												
Contact Herbicides												
Hand Weeding (organic)												
Fungicides												
Insect Scouting												
Disease Scouting												

Appendix 1, continued: Cultural Practices and IPM Calendars for California Potatoes

Desert Valley Production



Includes: Imperial, Riverside and Los Angeles counties

Cultural Practice	J	F	M	A	M	J	J	A	S	O	N	D
Bed Prep												
Fumigation												
Planting												
Fertilization												
Cultivation												
Vine Kill												
Irrigation												
Harvest												
IPM Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Soil Sampling												
Irrigation Scheduling												
Petiole Sampling												
Insecticides												
Preemerg, Herbicides												
Contact Herbicides												
Hand Weeding (organic)												
Fungicides												
Insect Scouting												
Disease Scouting												

Appendix 2: Seasonal Pest Occurrence in California Potatoes

Klamath Basin

DISEASES	J	F	M	A	M	J	J	A	S	O	N	D
Bacterial Ring Rot												
Bacterial Soft Rot												
Blackleg												
Calico												
Common Scab												
Corky Ring Spot												
Cucumber Mosaic												
Curly Top												
Early Blight												
Fusarium Dry Rot & Seed Piece Decay												
Late Blight												
Leafroll												
Leak (Water Spot)												
Pink Rot												
Powdery Scab												
Southern White Rot/Sclerotium Stem Rot												
Stem and Stolon Canker												
White Mold												
INSECTS/MITES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Aphids												
Beet Leafhopper												
Cutworms												
Flea Beetles												
Potato Psyllid												
Potato Tuber Worm												
Silverleaf Whitefly												
Wireworms												
NEMATODES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root Knot (and others)												
WEEDS	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Lambs quarters												
Nettle												
Nightshade, black/hairy												
Nut sedge, purple/yellow												
Quack grass												
VERTEBRATES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Mice												

Appendix 2, continued: Seasonal Pest Occurrence in California Potatoes

Delta Basin

DISEASES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bacterial Ring Rot												
Bacterial Soft Rot												
Blackleg												
Calico												
Common Scab												
Corky Ring Spot												
Cucumber Mosaic												
Curly Top												
Early Blight												
Fusarium Dry Rot & Seed Piece Decay												
Late Blight												
Leafroll												
Leak (Water Spot)												
Pink Rot												
Powdery Scab												
Southern White Rot/Sclerotium Stem Rot												
Stem and Stolon Canker												
White Mold												
INSECTS/MITES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Aphids												
Beet Leafhopper												
Cutworms												
Flea Beetles												
Potato Psyllid												
Potato Tuber Worm												
Silverleaf Whitefly												
Wireworms												
NEMATODES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root Knot (and others)												
WEEDS	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Lambs quarters												
Nettle												
Nightshade, black/hairy												
Nut sedge, purple/yellow												
Quack grass												
VERTEBRATES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Mice												
Birds												

Appendix 2, continued: Seasonal Pest Occurrence in California Potatoes

Kern County Region

Spring

DISEASES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bacterial Ring Rot												
Bacterial Soft Rot												
Blackleg												
Calico												
Common Scab												
Corky Ring Spot												
Cucumber Mosaic												
Curly Top												
Early Blight												
Fusarium Dry Rot & Seed Piece Decay												
Late Blight												
Leafroll												
Leak (Water Spot)												
Pink Rot												
Powdery Scab												
Southern White Rot/Sclerotium Stem Rot												
Stem and Stolon Canker												
White Mold												
INSECTS/MITES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Aphids												
Cutworms												
Flea Beetles												
Potato Psyllid												
Potato Leafhopper												
Potato Tuber Worm												
Silverleaf Whitefly												
Wireworms												
NEMATODES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root Knot (and others)												
WEEDS	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Lambs quarters												
Nettle												
Nightshade, black/hairy												
Nut sedge, purple/yellow												
Quack grass												
VERTEBRATES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Squirrels												

Appendix 2, continued: Seasonal Pest Occurrence in California Potatoes

Kern County Region

								Fall				
DISEASES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bacterial Ring Rot												
Bacterial Soft Rot												
Blackleg												
Calico												
Common Scab												
Corky Ring Spot												
Cucumber Mosaic												
Curly Top												
Early Blight												
Fusarium Dry Rot & Seed Piece Decay												
Late Blight												
Leafroll												
Leak (Water Spot)												
Pink Rot												
Powdery Scab												
Southern White Rot/Sclerotium Stem Rot												
Stem and Stolon Canker												
White Mold												
INSECTS/MITES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Aphids												
Beet Leafhopper												
Cutworms												
Flea Beetles												
Potato Psyllid												
Potato Tuber Worm												
Silverleaf Whitefly												
Wireworms												
NEMATODES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root Knot (and others)												
WEEDS	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Lambs quarters												
Nettle												
Nightshade, black/hairy												
Nut sedge, purple/yellow												
Quack grass												

Appendix 2, continued: Seasonal Pest Occurrence in California Potatoes

Desert Valley

DISEASES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bacterial Ring Rot												
Bacterial Soft Rot												
Blackleg												
Calico												
Common Scab												
Corky Ring Spot												
Cucumber Mosaic												
Curly Top												
Early Blight												
Fusarium Dry Rot & Seed Piece Decay												
Late Blight												
Leafroll												
Leak (Water Spot)												
Pink Rot												
Powdery Scab												
Southern White Rot/Sclerotium Stem Rot												
Stem and Stolon Canker												
White Mold												
INSECTS/MITES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Aphids												
Beet Leafhopper												
Cutworms												
Flea Beetles												
Potato Psyllid												
Potato Tuber Worm												
Silverleaf Whitefly												
Wireworms												
NEMATODES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root Knot (and others)												
WEEDS	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Lambs quarters												
Nettle												
Nightshade, black/hairy												
Nut sedge, purple/yellow												
Quack grass												
VERTEBRATES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Rabbits												
Gophers												
Squirrels												

Appendix 3: Efficacy of Insecticides for Insect/Mite Pests of California Potatoes

Product	Trade Name	Aphids	Leafhopper	Cutworms	Flea Beetles	Leafminer	Potato Psyllid	Potato Tuber Worm	Silver leaf Whitefly	Wireworms
ABAMECTIN	AgriMek®					F-G				
ACETAMIPRID	Assail®	G	G	F-G	F-G		G	G	F-G	
CARBARYL BAIT	Seven®			E			G-E			
ENDOSULFAN	Thionex®, Thiodan®	G					E			
ESFENVALERATE	Asana®	P	P	G-E	F-G		F-G	F-G	P	
ETHOPROP	Mocap®									G-E
IMIDACLOPRID	Provado®/Admire®	G	G	P	P-G		F-G	P	F-G	P
METHAMIDOPHOS	Monitor®	G-E	F	F-G	F	G	G	G	F	
METHOMYL	Lannate LV®	F	G	P-F	P			P	P	
PERMETHRIN	Pounce®	P	P	G-E	G		F-G	G	P	
PHORATE	Thimet®	G	G	P			G	P		G
SPINOSAD	Success®					F-G				
THIAMETHOXAM	Platinum®/Actara®	G							G	
Non-chemical Management Tools										
Pheromones								G		
Natural enemies		P-F	P-F							
Sanitation/disking host plants in area		G	G		G	G		G	G	

E = Excellent
G = Good
F = Fair
P = Poor
R = Known Resistance

Appendix 4: Relative Toxicity of Insecticides to Beneficial Organisms in California Potatoes

Product	Trade Name	Big-eyed but	Damsel bug	Green Lacewings	Lady Bird Beetles	Minute Pirate Bugs	Predatory Mites	Predatory Nematodes	Parasitic Wasps	Spiders	Syrphid Flies	Tachinid Flies	all
ACETAMIPRID	Assail®												+++
ESFENVALERATE	Asana®												++
ETHOPROP	Mocap®												+
IMIDACLOPRID	Provado®												++
METHAMIDOPHOS	Monitor®												+++
METHOMYL	Lannate LV®												+++
OXAMYL	Vydate®												+++
PERMETHRIN	Pounce®												++
PHORATE	Thimet®												+

Data Based on collective field observations and experiments (Growers, Pest Control Advisors, Farm Advisors, etc.)

Rating System:
0 = No Impact
+ = Soft
++ = Moderate
+++ = Harsh

Appendix 5: Efficacy of Weed Management Tools Used in California Potatoes

Product	Trade Name	Lambs quarter	Nettle	Nightshade	Nut sedge	Quack grass
EPTC	Eptam®	F	F	G	G	G
GLYPHOSATE, ISOPROPYLAMINE SALT	Roundup®	F-G	P-G	G	G	
METAM SODIUM	Vapam®	E	E	E	E	E
METOLACHLOR	Dual 8EC®	G	G	F-G	G-E	F
METRIBUZIN	Sencor/Lexone 75DF®	E	F	F	F	
PARAQUAT	Gramoxone Extra®	G	G	G		
PENDIMETHALIN	Prowl®	G	G	F	P	G
RIMSULFURON	Matrix®	P	F	G	F	
SETHOXYDIM	Poast®	P	P	P	P	G
TRIFLURALIN	Treflan®	G	P	G	P	
Non-chemical Tools						
Cultivation		G	G	F	F	G
Pre-irrigation		G	G	G	G	G

Data Based on collective field observations and experiments (Growers, Pest Control Advisors, Farm Advisors, etc.)

Rating System:
E = Excellent
G = Good
F = Fair
P = Poor / None
* = Seedling plants only (generally not effective on re-growth from perennial plants)

Appendix 6: Efficacy of Disease Management Tools Used in California Potatoes

Product	Trade Name	Bacterial Ring Rot	Bacterial Soft Rot	Blackleg	Calico	Common Scab	Corky Ring Spot	Cucumber Mosaic	Curly Top	Early Blight	Fusarium Dry Rot & Seed Piece Decay	Late Blight	Leafroll	Leak (Water Spot)	Pink Rot	Powdery Scab	Southern White Rot Sclerotium Stem Rot	Stem & Stolon Canker	White Mold
1,3-DICHLOROPROPENE	Telone®						F-E*												
AZOXYSTROBIN	Quadris®									G		F					F-G	G	G
BOSCALID	Endura®									G								F	G
CHLOROPICRIN	Chloropicrin®																		
CHLOROTHALONIL	Bravo®									F		F		F	F	F			
COPPER HYDROXIDE	Kocide®	P	P	P						P		P							
CYMOXANIL	Curzate®											G							
DIMETHOMORPH	Acrobat®											G							
FLUDIOXONIL	Maxim®		F	F							P-G							F-G	
FENAMIDONE	Reason®											G							
IPRODIONE	Rovral 50 WP®									G									P-G
MANCOZEB	Manzate® Penncozeb® Dithane®		F							F-G	G	F							
MANEB	Maneb 75 DF®									F-G		F-G						F	
MEFENOXAM/ METALAXYL	Ridolmil Gold®											R		F	F	F			
METAM-SODIUM	Vapam®						G				G					F	G		F-G
OXAMYL	Vydate®						G												
PYRACLOSTROBIN	Headline®			F							F-G							P-F	P-F
THIOPHANATE METHYL	Topsin M®																	G	
SULFUR	Sulfur					G													
STREPTOMYCIN	Agromycin®		F	F															
Non-chemical Tools																			
Models																			
Vector management																			
Irrigation management																			
Natural enemies																			
Weed control																			
Resistant varieties																			
Cover crops											E								
Post Harvest Crop Destruction																			

*Depending on soil type.
Data based on collective field observations and experiments (Growers, Pest Control Advisors, Farm Advisors, etc.)

Rating System:
E = Excellent F = Fair R = Known Resistance G = Good P = Poor / None

Appendix 7: Efficacy of Nematode Management Tools Used in California Potatoes

Product	Trade Name	Root Knot Nematode (and others)
1,3-DICHLOROPROPENE	Telone®	P (organic soils) E (non-organic) very expensive
ETHOPROP	Mocap®	P-G
METAM SODIUM	Vapam®	P-G
OXAMYL	Vydate®	G
Non-chemical Tools	-	
Fallow	-	G
Monitoring-soil samples	-	G
Soil/water management	-	G
Resistant seed	-	N/A
Rotation	-	G

Data Based on collective field observations and experiments (Growers, Pest Control Advisors, Farm Advisors, etc.)

Rating System:
E = Excellent
G = Good
F = Fair
P = Poor / None
R = Known Resistance

Appendix 8: Relative Toxicity of Fungicides/Nematicides to Beneficial Organisms in California Potatoes

Product	Trade Name	Mycorhizae	Trichoderma	Glieocladium
1,3-DICHLOROPROPENE	Telone®	+	+	+
AZOXYSTROBIN	Quadris®	+++	+++	+++
BOSCALID	Endura®	+++	+++	+++
CHLOROTHALONIL	Bravo®	+++	+++	+++
COPPER HYDROXIDE	Kocide®	+	+	+
CYMOXANIL	Curzate®	+	+	+
FLUDIOXONIL	Maxim®	+++	+++	+++
IPRODIONE	Rovral 50 WP®	+++	+++	+++
MANCOZEB	Tops®	+++	+++	+++
MANEB	Maneb 75 DF®	+++	+++	+++
MEFENOXAM/METALAXYL	Ridomil Gold®	+	+	+
METAM-SODIUM	Vapam®	+++	+++	+++
OXAMYL	Vydate®			
THIOPHANATE METHYL	Topsin M®	+++	+++	+++
SULFUR	Sulfur	+	+	+

Data Based on collective field observations and experiments
(Growers, Pest Control Advisors, Farm Advisors, etc.)

Rating System:
0 = No Impact
+ = Soft
++ = Moderate
+++ = Harsh

Appendix 9: Efficacy of Vine-kill/Sprout Inhibitors Used in California Potatoes

Product	Trade Name	
DIQUAT DIBROMIDE	Diquat®/Reglone®	F-G
ENDOTHALL, MONO [N,N-DIMETHYL ALKYLAMINE] SALT		
MALEIC HYDRAZIDE, POTASSIUM SALT	MH-30®	G
PARAQUAT DICHLORIDE	Gramoxone®	

Data Based on collective field observations and experiments (Growers, Pest Control Advisors, Farm Advisors, etc.)

Rating System:
E = Excellent
G = Good
F = Fair
P = Poor / None

Appendix 10: Efficacy of Vertebrate Management Tools Used in California Potatoes

Product or Technique	Squirrels	Gophers	Pigs	Voles	Rabbits	Deer	Birds
Chlorophacinone (Rozol)				G			
Diphacinone (Ramik)				G			
Zinc-phosphide				G			
Trapping							

Data based on collective field observations and experiments.

Rating System:
E = Excellent
G = Good
F = Fair
P = Poor / None
R = Known Resistance
NR = Not Registered

Appendix 11: Major Chemical Use in California Potatoes in 2003

Chemical Name	Trade Name	Acres Treated Base	Acres Treated Cum.	Pounds Active Ingredient
METAM-SODIUM	Vapam®	9,275	9,623	1,402,213
1,3-DICHLOROPROPENE	Telone®	2,763	2,763	188,687
MANCOZEB	Dithane®	23,184	46,643	54,979
CHLOROTHALONIL	Bravo®	21,626	46,263	50,227
CHLOROPICRIN		1,031	1,031	44,944
MALEIC HYDRAZIDE, POTASSIUM SALT	MH-30®	11,585	11,626	37,131
EPTC	Eptam®	6,505	8,767	24,111
PHORATE	Thimet®	5,245	5,578	13,229
COPPER HYDROXIDE	Kocide®	5,101	9,504	12,123
ETHOPROP	Mocap®	1,330	1,330	11,510
DIQUAT DIBROMIDE	Diquat®	10,150	11,400	9,441
MANEB	Maneb 75 DF®	4,297	7,882	8,897
PENDIMETHALIN	Prowl®	8,159	8,438	6,842
OLEIC ACID, METHYL ESTER		2,801	3,152	6,803
METHAMIDOPHOS	Monitor®	5,932	7,446	6,426
METRIBUZIN	Sencor/Lexone 75DF®	10,315	11,014	3,987
METHOMYL	Lannate LV®	3,086	4,630	3,648
AZOXYSTROBIN	Quadris®	14,255	20,390	2,992
IPRODIONE	Rovral 50 WP®	1,834	2,590	2,272
CYMOXANIL	Curzate®	12,094	18,197	2,164
GLYPHOSATE, ISOPROPYLAMINE SALT	Roundup®	2,178	2,183	2,035
SULFUR		271	271	1,864
PERMETHRIN	Pounce®	5,481	7,654	1,640
PETROLEUM OIL, PARAFFIN BASED		3,083	4,137	1,444
MANGANESE SULFATE		2,873	7,236	1,419
MEFENOXAM/METALAXYL	Ridomil Gold®	8,453	12,258	1,083
ENDOTHALL, MONO [N,N-DIMETHYL ALKYLAMINE] SALT		765	1,204	1,032
IMIDACLOPRID	Provado®/Admire® Leverage®	5,039	6,694	954
ESFENVALERATE	Asana®	8,625	12,437	607
TRIFLURALIN	Treflan®	618	618	513
RIMSULFURON	Matrix®	12,066	13,443	288
SETHOXYDIM	Poast®	921	938	283
PARAQUAT DICHLORIDE	Gramoxone®	174	174	121
ABAMECTIN	Agri-Mek®	641	1,021	15

Note: For a complete list of all products used in this crop, please refer to http://www.cdpr.ca.gov/docs/pur/pumain.htm. The above reported chemical use data was the most recent CDPR information available at the time of publication.

Appendix 12: California Potato Industry Contact Information (Tulelake Workgroup)

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Appendix 13: California Potato Industry Contact Information (Kern Workgroup)

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