Colorado Late Blight Management Plan for 2008

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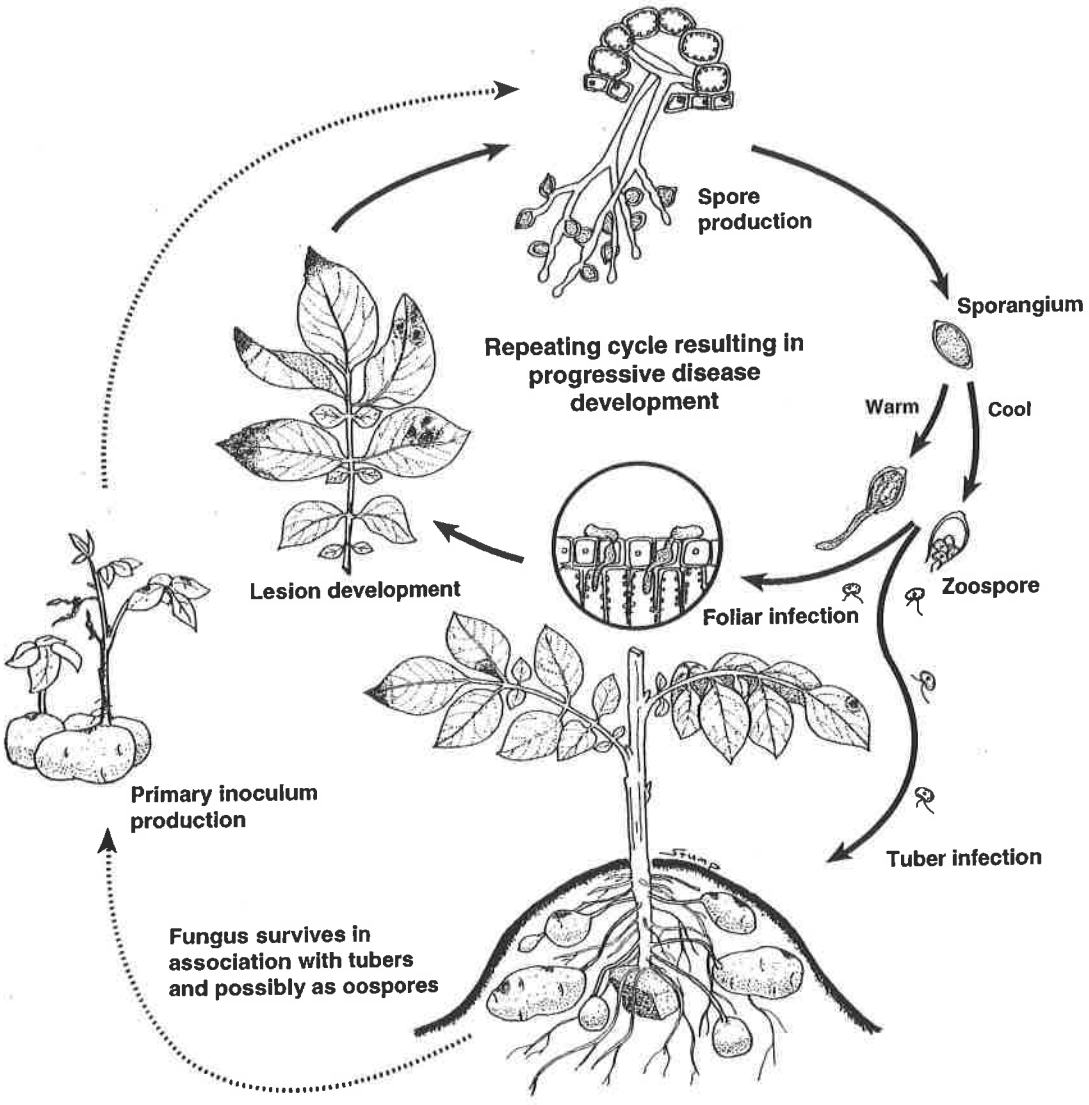
(in part using "Idaho Late Blight Action Plan - 1998", revision: May 2, 1998
authors: Nolte, Ojala, Mohan & Bohl)



Disease cycle of late blight of potato and tomato caused by *Phytophthora infestans*
Diagram obtained from Potato Late Blight, University of Wyoming Extension Bulletin #B1032, May 1996.
Authors: Gary Franc, Bill Brown and Eric Kerr.

Colorado State University Recommendations for Integrated Management of Potato Late Blight

Destroy Cull Piles and Eliminate Volunteers:

- Destroy cull potatoes by composting, burial, chopping, freezing, or feeding to livestock prior to new crop emergence.
- Monitor cull disposal sites and treat emerging sprouts with herbicides.
- Exercise most vigilance for destroying cull potatoes in a timely, acceptable manner during the growing season (May 15th - October 1st).
- Control volunteers with a combination of cultivation, herbicides and suppressive crops.

Use Certified Seed:

- Select seed lots carefully to avoid bringing in late blight on the seed. It is especially important to contact seed growers prior to winter to be certain that the seed lots of interest are available and will be sorted and graded to your specifications.
- Do not plant "year out" seed.
- Save suspect seed pieces during cutting and have them evaluated by an expert.
- Do not mix seed lots.

Scout Fields for Late Blight:

- Scout fields at least twice a week, beginning when plants are six inches in height.
- Concentrate scouting on low-lying areas, field edges, the center tower of pivots, wet and shaded areas, and any place where fungicide application is difficult.

Protect Plants with Fungicide:

- Apply protectant fungicides before late blight appears.
- Make the first fungicide application prior to plants touching within the row.
- Continue fungicide applications at intervals determined by the potential for late blight following the forecasts and recommendations from Colorado State University and local crop care providers.
- Use the correct nozzles, pressure and water volume to ensure thorough coverage of the foliage and avoid application skips.

Harvest Only After Vines Are Completely Dead:

- Time vine kill so that leaves and stems are completely dead at least two weeks prior to harvest, or at the earliest time acceptable tuber size has been reached.
- If late blight is found in the region, continue fungicide applications until vines are completely dead.
- Avoid harvesting wet tubers and minimize skinning, cuts and shatter bruise.
- Harvest tubers as soon as acceptable skin set has been achieved. This will also reduce the impact from other soil borne diseases such as silver scurf and *Rhizoctonia*.

Manage Storages to Reduce Decay:

- Sort tubers coming into storage and remove decayed tubers.
- Do not plan on long-term storage if more than 2% of the tubers show late blight.
- Begin monitoring the pile for hot spots immediately.
- Dry and cool the pile quickly by utilizing large volumes of air.

Colorado Late Blight Management Plan - 2008
Summary

INTRODUCTION

Occurrence in Colorado

- The genotype currently found in Colorado (US-8) is classified as aggressive and resistant to metalaxyl or mefenoxam (Ridomil).

Spreading of late blight

- Inoculum is produced on volunteer potato plants, from cull piles, or infected seed.
- Infected plants produce spores that can be carried in moist air for long distances (50 miles+).

CULTURAL CONTROL METHODS

Before planting

- Reduce or eliminate inoculum sources; cull piles, infected volunteer potato plants from the previous season, and infected seed potatoes.
- Plant only certified seed which has been inspected and/or screened for late blight.
- Select fields for planting potatoes having good water infiltration and drainage characteristics.
- Do not plant potatoes in areas of fields where plants cannot be sprayed with fungicide.

During planting

- Do not mix seed lots to avoid possible contamination between diseased and disease-free seed.

Early season

- Cultivate fields to increase water infiltration and control weeds.
- Form high, wide hills to reduce exposing tubers to late blight spores that may be washed from infected plants.
- Scout fields regularly, concentrating in areas that remain wet for extended periods of time.
- Look for early indications of late blight on volunteer potatoes and monitor cull disposal sites.

Mid-season

- Apply heavier, less frequent water applications rather than light, frequent ones.
- For evening irrigation sets, consider beginning after midnight when dew would normally wet the leaves anyway.
- Continue scouting, especially low lying areas, pivot corners, field borders, and weedy patches.
- Although late blight readily spreads with moist air, to reduce risks, people entering fields may want to wear high boots that can be disinfected between fields , or wear disposable boots and pants that can be changed between fields, and reused after washing and drying.
- Destroy small patches of late blight infected potato plants in the field as soon as possible after discovery.

Late season

- Avoid excessive irrigation.
- Avoid late season fertilizer applications.
- Continue scouting to identify and mark late blight infected spots in fields.
- Kill vines at least two to three weeks prior to the anticipated harvest date making sure the vines are completely dead.

Harvest and storage

- Remove as many decayed tubers as possible coming into storage during harvest.
- Avoid harvesting during wet conditions, before skins are mature, and minimize skinning, cuts and shatter bruises.
- Remove vines, loose soil, and anything else that may interfere with air distribution in the pile.
- If foliar late blight was present in the field, dry tubers as quickly as possible after placed in storage. Plan to rapidly reduce storage temperatures to 38-40^{0}F to retard decay if longer term storage is contemplated.
- Immediately begin observing potatoes in storage for developing hot spots.
- Supply additional air to hot spots in storage and remove potatoes as soon as possible.
- Use shallow tillage practices that leave tubers on the surface or within the top two inches of soil to encourage freezing during the winter.

CHEMICAL CONTROL

Selecting a fungicide

- A list of fungicides labeled for potatoes for controlling late blight is included in the action plan.
- The fungicide selected is not as important as having complete coverage and proper timing for the disease pressure present in the area.
- Using copper or tin fungicides alone is not recommended for controlling late blight. These products provide excellent control when used in combination with other fungicides.

Consider these factors when selecting and using an application method

- Chemical label instructions dictate if a fungicide may be applied by ground, air or chemigation.
- Field size, shape, tillage practices, and obstacles that may hinder application.
- If using air or ground applications, be certain the equipment will be available when needed.
- Be sure the field is completely covered and fungicides are applied at the proper time during the season and that intervals between applications are appropriate and follow the label. Rotate chemistries (especially systemic or translaminar types) to avoid pathogen resistance.
- With air or ground applications, an irrigation may be needed to redistribute the chemical uniformly through the crop canopy.

Application methods

- Always use the highest rate of fungicide allowed regardless of application method or fungicide combination.

Ground application

- Apply at least 20 gallons of water per acre; 50 gallons may improve coverage.
- Adjust sprayer pressure towards the upper operating range recommended for the nozzle type.
- Use hollow cone and extended range flat fan nozzles.
- Re-calibrate the sprayer often and replace nozzles that are under or over applying by more than 10%. Raise the boom height as the crop grows to maintain the proper overlap in spray pattern.

Air application

- Use 5 gallons of water per acre; more water does not improve coverage and distribution.
- Calibrate nozzle output often and replace those that are under or over applying by more than ten percent.
- Skips can be avoided by marking spray passes with permanent flags and alternating spray passes on the flags and between flags on subsequent applications.
- Use a ground applicator to spray areas missed or inaccessible by air application.

Sprinkler application

- Use appropriate chemigation equipment making sure the injection pump operates the entire set.
- Use the highest labeled rate of fungicide to ensure an effective concentration on the leaves.
- For all irrigation systems, make sure there are no potatoes outside of the water coverage area.
- For solid set, inject the fungicide during the last 15 minutes of the irrigation set, or make a separate application between irrigations. Make sure the fungicide has flushed out of the end nozzles before shutting off the system.
- For center pivot systems, adjust the revolution time to the fastest setting to reduce fungicide wash off.

When to apply fungicide

Initial applications

- All fields should be sprayed with a protectant fungicide before row closure followed by a second application in seven to ten days.

Applications through late season

- Rigorously scout fields for late blight and access the CSU VegNet to obtain the most up-to-date information regarding weather, disease forecast models, disease sightings and IPM strategies.
- If late blight is found in the area or weather conditions are conducive for disease development, continue spraying protectant fungicides.
- If late blight is found in the field, use of the systemic and/or translaminar type fungicides is warranted and should be considered to hold the infection in check. Use of protectant fungicides for early protection makes it much more effective to control the disease spread in-field and out-of field. Be sure to follow label directions, rotate the various chemistries and alternate a protectant type fungicide between applications of the systemic/translaminar fungicides or use in the mix as directed.

Late season

- Continue fungicide applications at intervals based on weather conditions and recommendations.
- Protectant fungicides may need to be applied even after vine desiccation, until all green vines are completely dead, if late blight was present in the region or field.

Recommendations to reduce late blight tuber rot

- Provide season-long control of the late blight fungus on the vines (leaves and stems).
- Follow the recommendations above to reduce the chance of tuber infection during harvest.

INTRODUCTION

Development and use of this action plan

A large portion of this action plan was developed for use with the Idaho potato industry in consultation with late blight experts in the Pacific Northwest and other areas of the United States. Colorado State University would like to express their appreciation for Idaho's willingness to allow us to use major portions of their action plan intact (Nolte, Ojala, Mohan & Bohl, "Idaho Late Blight Action Plan - 1998", revision: May 2, 1998), while tailoring other parts to fit Colorado's circumstances. It is our hope that the information in this action plan will help Colorado's potato industry by reducing the potential impact on yield and quality caused by late blight. This action plan should also help growers and other agriculture personnel in making informed decisions about prevention and fungicide spray programs, and minimize disease management costs. Additional information about late blight can be obtained by contacting either the San Luis Valley Research Center or the Colorado State University Department of Bioagricultural Sciences and Pest Management.

Occurrence in Colorado

Late Blight is the most important disease of potatoes on a world-wide basis. Prior to 1995 in northern Colorado, and 1998 in the San Luis Valley, only one isolated case of late blight had been reported in the previous decade. However, late blight appeared in numerous fields in northern Colorado in 1995 and 1996 with significant impact on the crop. Late blight did not appear in the San Luis Valley until mid-August, 1998 and 1999, primarily focused northwest of Center in the early stages of the epidemic, and valley-wide by the end of August. The late blight strain identified in both the northern Colorado outbreaks and the San Luis Valley outbreak was US-8. This particular strain is extremely aggressive on potato and is occasionally found on tomato. In 2007, late blight was again identified in the San Luis Valley, only this time in the southern end of the Valley near Mesita. This outbreak began at the end of July and moved as far north as the Mosca area. Fortunately, identification was made in a relatively timely fashion and most growers with the disease were notified either by CSU personnel or by local ag consultants/fieldmen. All growers contacted agreed to sell any identified late blight potatoes on the commercial market rather than replant them as seed in 2008. Again, this strain was identified by Michigan State University as being US-8. It is of particular importance that the amount of organically produced potatoes be considered. In the outbreaks of 1998/99, there were many fewer acres of organic potatoes than there were in 2007. Late blight can make organic production difficult, if not almost impossible, due to the severe limitations on use of major chemistries/chemicals to fight the disease. As such, it is of critical importance that the potato industry in the San Luis Valley use any measures possible to try to eradicate this disease from Valley potato stocks as was accomplished in the late 1990's.

Spread of late blight

Potatoes may be exposed to late blight during the growing season from inoculum produced on infected cull piles, volunteer potato plants, or the disease may originate from infected seed. Also, tomato transplants in the home gardens may be infected with late blight. Under the right conditions, spores from infected plants can be carried in moist air, such as thunderstorms, for miles (documented cases of 50 miles+). Under favorable conditions, these spores infect healthy plants, thus spreading the disease. There are many new chemistries available to fight this disease that were not present in the 1990's. Many of the new chemicals will effectively move in the plant, either translaminar or in some case systemically, to help limit sporulation and control the late blight fungus strains even after they have become established in a plant. However, it is still

of critical importance that everyone associated with the potato industry develops a "late blight prevention attitude" to keep fungicide costs to a minimum. An effective prevention program includes implementing cultural and chemical management practices that reduce the potential for occurrence, spread and losses from late blight.

CULTURAL CONTROL METHODS

Before planting...

Learn to recognize late blight symptoms...Early detection and treatment are important for controlling late blight. Familiarize yourself with the leaf, stem and tuber symptoms of late blight so that you can recognize this disease. Refer to the color plates included in this bulletin.

Understand conditions favoring development...Late blight is more likely to develop during periods of high humidity and temperatures between 55^0 to 80^0F. Even in the absence of rainfall, sprinkler irrigation provides ideal conditions for late blight development.

Eliminate sources of inoculum...The initial sources of late blight inoculum are likely to be infected plants in cull piles, volunteer potato plants infected the previous year and which have survived the winter, and infected seed tubers. In addition, infected potato and tomato plants in home gardens and nurseries can serve as sources for late blight.

Regulations from the Colorado Department of Agriculture mandate specific recommendations detailing how cull potatoes and other non-usable material and waste from all potato operations, including seed cutting operations, should be disposed of, or handled in a manner that makes them unable to support late blight spore production. These regulations are in effect from May 15^{th} or the time of plant emergence until September 20^{th} or vine death. Methods for disposing of cull potatoes include freezing, chopping, feeding to livestock, composting and burial.

When soil temperatures at the 4 to 6 inch depth have not reached 20^0 to 25^0F during the winter, volunteer potato plants may be very common. While this is not frequent in Colorado, it does occasionally happen. Use cultivation and labeled broadleaf herbicides where possible to suppress the growth of volunteer potatoes in rotation crops. Check with your local extension office for herbicides available for use for controlling volunteer potatoes. Potato fields directly downwind from fields that had late blight the previous season may be at higher risk for late blight because of the potential movement of spores from infected volunteers.

Planting "eliminator" or "year out" seed is risky because of the possibility of having late blight infected tubers in the stocks. This practice is quite common in the San Luis Valley and can provide an ideal means for prolonging the late blight epidemic as well as other serious viral disease problems. However, purchasing certified seed is not a cure all. Purchase certified seed from a seed operation with which you are familiar. Examine all of the pertinent documentation available from the Potato Certification Service and the seed grower including field inspection records to verify disease levels, class of seed, kill down dates, etc. of the seed lots that you are considering for purchase and examine shipping point inspection records or, if not routinely done, request a shipping point inspection if there are any questions about the grade, size, disease content, etc. of the seed lots. Remember, the occurrence of foliar late blight in the potato crop does not mean that the tubers are infected, but there is an increased risk.

If purchasing seed from out-of-state, recognize that there are requirements for importing seed potatoes into the San Luis Valley. These regulations from the Colorado Department of Agriculture require that all seed lots be accompanied by an inspection certificate that indicates that no late blight was present in the field during

the growing of the crop or at the time of loading the seed for shipment. Additionally, each load must be accompanied by a document that shows proof that a representative sample of tubers from the load(s) was tested for late blight using the protocols as stated in the regulations. Finally, each load of seed that was found to be negative during the growing, loading, and testing, must be inspected by an official Colorado Department of Agriculture employee at the time of unloading (see the regulations in the appendix).

Avoid conditions that favor late blight...Weather conditions strongly influence the incidence and severity of late blight. Cool (55^0 to 80^0F), rainy weather, high relative humidity (near 100%), and heavy dew formation favor infection, disease progress and spore production. Although weather conditions are beyond our control, field selection and carefully managing irrigation practices can help reduce the extent of periods favorable for disease development.

If problems with uniform water application have occurred in the past, consider re-nozzling or making other modifications to your irrigation systems to reduce over-application and mis-application of water. Low spots, areas near the center tower of a center pivot system, or areas next to wind breaks, buildings, etc. tend to stay wet for long periods, which favors late blight development. Also, areas of fields next to wind breaks, houses, or power lines, or areas of the field outside of the irrigation systems reach, tend to be difficult to cover with fungicides applied by plane or by chemigation, and are often locations where late blight first appears. Avoid planting potatoes in areas of the fields where plants cannot be adequately protected with fungicides, or are at high risk for infection, such as half of the first span of a center pivot irrigation system. Another option for center pivots is to install valves that allow you to turn off the first few nozzles of the center tower to avoid keeping this area excessively wet.

Excessive nitrogen applications promote heavy vine growth extending the period during which relative humidity within the canopy remains above 90%, a level favoring spore production and leaf infection. Develop a nitrogen management plan that promotes optimum plant growth and yields without stimulating excessive vine growth. This can be especially critical when growing the larger vine type cultivars such as the Russet Norkotah selections, Russet Nugget, Chipeta, or many of the finglerling-type potatoes.

Grow less susceptible cultivars...All commercial potato cultivars grown in Colorado are considered susceptible to late blight. Early maturing, determinate cultivars such as Russet Norkotah, however, seem more prone to yield losses because defoliation tends to progress rapidly, and diseased leaves are not replaced by new growth. Cultivars with heavy canopies or those that are later maturing, such as Russet Nugget, may be more difficult to treat effectively with fungicides and may require a much higher production cost during the season to obtain a saleable crop. It is not uncommon to see late blight spread rapidly in the under-foliage of these type of cultivars, so early applications of protectant type fungicides prior to row closure can be a great value. Also, those cultivars setting tubers high in the hill or near the surface of the soil seem to be very susceptible to tuber infection. It is important to note that susceptibility to foliar infection does not seem to be directly related to the level of tuber infection.

During planting...

Do not mix seed during cutting...Keep seed lots separate to avoid mixing clean lots with seed lots potentially infected with late blight. Mixing healthy and infected seed lots will spread the disease over a larger area. During the cutting operation, eliminate and save suspected seed pieces that show a rust brown, firm decay typical of late blight. Bring or send suspicious tubers to SLV Research Center or CSU for positive identification.

Late blight may spread readily from infected tubers to freshly-cut surfaces and to sprouts of healthy seed tubers during the cutting operation, so it is wise to keep cutter knives sharp to minimize jagged cuts that may contribute to spreading this disease to healthy seed pieces. There are no seed piece treatments currently labeled for controlling late blight, but using a labeled seed piece treatment that contains an EBDC such as mancozeb may help reduce the spread of the late blight fungus. If possible, store seed at less than 45^{0}F, then warm and cut just before tubers begin to sprout. This will help reduce the green tissue available to the late blight fungus for colonization. Also, to minimize disease spread between seed lots, always clean and disinfect equipment between lots.

Early Season...

Do not let cull potatoes accumulate...Eliminating cull potatoes early in the season is critical because these potatoes could potentially carry the late blight fungus. Potato pieces resulting from seed cutting operations or cull potatoes left after loading or unloading at storage facilities may support the production of late blight spores whether or not the pieces are sprouting, and should be disposed of properly. Because freezing is generally not an option in the spring, daily burial or feeding to livestock may be appropriate methods of disposing of cull potatoes. Do not allow cull piles to build up at feeding areas! Check with the Colorado Department of Agriculture, local county officials, or review the section detailing cull pile management in this document to answer questions on how to properly dispose of cull potatoes in your area. Keep in mind that potatoes may sprout and produce plants even when buried to depths greater than two feet, so it is important to continually monitor disposal sites and prevent volunteer plants from developing.

Cultivate and properly hill fields...Cultivating and hilling early may promote better water infiltration and reduce weed populations. Form high, broad hills to help minimize exposure of tubers to late blight spores that may be washed from infected plants. This type of hill will provide an added benefit of reducing green potatoes later in the season. Use of equipment such as Dammer-Dikers will help increase water infiltration and minimize water ponding in the field.

Control alternate hosts...Hairy nightshade can be infected with late blight and may contribute to disease spread under some conditions. Infections of nightshade were confirmed in 1998 and 1999 in the San Luis Valley. Apply effective pre or post emergence herbicides such as Eptam or Matrix during the early season to reduce hairy nightshade populations. Although other weed species are not hosts of late blight, they can contribute to conditions that favor disease development in the potato crop by restricting air movement within the canopy. Heavy weed infestations also prevent adequate coverage of potato foliage with fungicides. Use information available from Colorado State University or your local crop care providers to plan an effective weed control program.

Scout fields regularly...Closely monitor the growing crop and submit any suspected late blight samples to the CSU Extension Service for identification. Concentrate scouting in areas of fields that tend to stay wet for long periods such as the center pivot wheel tracks and low areas where water collects. Especially scout plants under the innermost tower of center pivots because this area is almost constantly wet which is conducive for late blight development. The windward sides of fields are usually the earliest infected from wind-borne spores, so check these areas first. Also, concentrate scouting in areas that may have escaped a fungicide application because of power lines, trees or other obstacles. Look for early indications of late blight on volunteer potatoes, particularly in fields that had late blight the previous year.

Forecasting...Forecasting models have been, and are currently being used in Colorado. Results have been mixed, but Colorado State University will continue to assess the existing models and refine these to develop a system that will accurately forecast late blight across the state.

Mid-season...

Irrigation management...A leaf needs to remain wet for about 8 to 10 hours in order for late blight spores to germinate and infect a plant. The longer the leaves remain wet, the greater the risk of getting infected with late blight. Avoid irrigating during, or immediately after periods of cold, rainy weather. Delaying irrigation too long, however, may increase chances for developing disorders such as sugar-ends and mis-shapen tubers. When possible, allow the plant foliage to completely dry between irrigations. Heavy, less frequent water applications may be better than light, frequent ones during the mid-season. For irrigations applied during the evening, consider beginning after midnight when dew would normally wet the leaves anyway. For solid set sprinklers, consider watering for periods of less than 8 hours to prevent the plants from remaining wet for this length of time; the time frame necessary for infection to occur.

If large wet spots from in localized areas of a field, make sure the system is not leaking, and if necessary, make repairs or turn off nozzles to allow these spots to dry.

Scouting...Continue scouting fields, especially low lying areas, field borders, weedy patches, and any place where lack of air movement or shading allows leaves to remain wet for prolonged periods. Submit suspect samples to your local Extension office for positive identification. Continue monitoring cull disposal sites and volunteer potatoes so that they can be treated with herbicide before the foliage can act as a source of late blight inoculum.

Sanitation practices...Although late blight is more likely to be spread from field to field by wind than by contact with people, it is unwise for any industry personnel to take risks. Therefore, people entering fields may want to wear high boots that can be disinfected between fields with products such as diluted household bleach (Chlorox) mixed 1 part bleach to 9 parts water. An alternative is to wear disposable boots and pants that can be changed between fields and reused after washing and drying.

Destroy hot spots...Current knowledge indicates that when late blight infestations are found early in small patches, it may be beneficial to disk, burn with a propane burner, or spray these patches with a desiccant (preferably sulfuric acid) to remove local sources of inoculum. The area to be killed needs to extend at least 25 feet beyond the visible symptoms. While this can be effective, remember visible late blight lesions may appear three to five days after leaves become infected. If conditions were favorable for disease spread during these three to five days, killing an infected area after symptoms have appeared may not have been done soon enough to prevent further spread of the disease. These areas should also be marked (flagged) and inspected prior to harvest for presence of late blight in the tubers. Also of note, is how rapidly the most common strains of late blight will spread in the field. It is not usual to have aggressive strains like US-8 show initial symptoms in one week and, without proper treatments in place, to destroy most of the foliage in the field by the end of the next week. Thus, proper scouting, quick response on the treatments, and managing the crop are essential to avoid excessive losses.

Weather forecasts...Colorado State University has been utilizing a couple of late blight forecasting models that use precipitation, temperature and relative humidity to predict when the risk of late blight is high. These forecasting models were originally developed for potato production regions in the eastern U.S., but our experience indicates that they are useful under irrigated conditions in the west. Other forecasting methods are always being evaluated. Recommendations to intensify scouting efforts will be made when conditions become favorable for late blight. These models also provides recommendations for fungicide spray intervals based on weather and the stage of crop growth. This information will be available through your county Extension office, Northern Colorado (970) 356-4000 and the San Luis Valley (719) 754-3494 Extension 39. Weather information for the five weather stations located in the San Luis Valley [Center (CTR01, CTR02),

Blanca (BLA01), LaJara (LAR01), and San Luis (SAN01)] can also be obtained from the CSU CoAgMet system at the web site http://www.colostate.edu/Orgs/VegNet/ or http://www.CoAgMet.com.

Late season...

Avoid excessive irrigation...Potato tubers become infected with late blight when spores wash down from infected leaves and stems through cracks in the soil surface. Spores may directly contact tubers exposed through soil cracks, or may swim short distances through the soil to infect shallow tubers. In either case, excess moisture from irrigation may increase tuber infection.

Monitor and regulate fertility...Late season fertilizer applications help maintain green vines and promote tuber bulking. Remember, however, that green and vigorous vines are better hosts for late blight and can also be difficult to kill with desiccants, and immature tubers are more prone to skinning at harvest. Green vines may also harbor late blight spores that can infect tubers during harvesting, and skinned tubers may be more susceptible to infection. At the end of the season, based upon a producer's tuber size requirements, petiole nitrate levels should drop below 10,000 ppm to encourage vine senescence in all cultivars.

Scout fields regularly...Continue scouting on a weekly basis to identify hot spots of late blight infection. Infected areas should be flagged and harvested last so infected tubers have time to decompose, or you may want to avoid harvesting these areas. Tubers from these areas should be placed near the door in a storage to market potatoes immediately if tuber decay becomes evident. Even small amounts of foliar infection may lead to significant tuber infection if green vines are present during harvest.

Kill vines completely...Late blight cannot survive and produce spores without green foliage or stem tissue. During harvest, infected vines mixed with tubers may lead to tuber infections that become evident later in storage. Kill vines at least two to three weeks prior to the anticipated harvest date, or at the earliest time that acceptable tuber size has been achieved. This interval minimizes the chance of tubers getting contaminated with late blight spores during harvesting, and allows previously infected tubers to decompose in the field. Mechanical, chemical, burning or natural (frost) methods may be used to dessicate the vines. No data are available that suggests one method is better than another as long as vines are completely killed. Sulfuric acid and/or burning with propane, however, may be preferred over the others since they act to kill the late blight fungus and spores on the soil surface which may infect the tubers. Vine rolling or flailing may be helpful to expose the soil and lower canopy to drying in fields with heavy vines. Rolling also seals soil cracks and may reduce the potential for tuber infection. However, if there are high levels of foliar late blight in the crop, vine chopping may act to spread inoculum to other uninfected fields. Use good judgement when considering the appropriate vine killing methods, realizing that any of the methods must result in vines that are completely dead! Some vine kill methods are very sensitive to weather conditions. Watch weather forecasts and, if necessary, kill vines early if wet conditions are forecast.

Harvest and storage...

Identify level of tuber infection...Sort tubers coming into storage during harvesting, removing as many decayed tubers as possible. Identifying tubers infected only with late blight can be difficult at this time of year, especially if tubers are covered with soil. It is important to verify what type of rots may be present. Therefore, wash the tuber samples and have them evaluated by Colorado State University personnel or experienced local consultants/fieldmen. Potato lots with more than 5% late blight tuber rot can be very difficult to store and even lower percentages of late blight in marginal storage facilities can cause serious problems, so it is important to know what level is present.

Harvest carefully...Avoid harvesting during wet conditions, before skins are mature, and minimize skinning, cuts and shatter bruise that provide ideal places for late blight, and other diseases, to gain entry into the tubers. Although late blight does not need a wound to infect tubers, those tubers which are cut, skinned or shatter bruised are more likely to become infected because damaged areas remain wet for an extended time period, giving late blight time to infect the tuber. Remember, late blight is a water mold needing about eight to ten hours of continuous moisture to infect a plant or tuber.

Carefully monitor and regulate storage conditions...The ability to provide high volumes of air throughout the pile for drying tubers is critical during the early storage period. Remove vines, loose soil, and anything else that may interfere with air distribution in the pile. If foliar late blight was present in the field prior to harvest, it is important to dry the tubers as quickly as possible in storage. It may be necessary to continuously run the fans with reduced or no humidity until tubers are completely dry, usually less than 72 hours. Expect increased pressure bruise and shrinkage losses in potatoes subjected to these storage conditions, especially if they are not marketed early. Begin observing potatoes in storage immediately for developing rotting areas known as hot spots. If hot spots develop, supply additional air to that area of the cellar, and plan on removing the potatoes as soon as possible.

Minimize volunteer potatoes...Small tubers left in the field are potential volunteers the next year, and if infected, may produce late blight infected plants. The number of tubers left in the field may be reduced by using narrower pitch chain on the harvester. However, this may also increase the soil load in the harvester, and the soil must be removed before placing potatoes in storage so as not to hamper air circulation. Use a collector bin on the trash chain to gather discarded tubers so these can be spread in a thin layer on the edge of the field where they are more likely to freeze. Use shallow tillage practices that leave tubers on the surface or within the top two inches of soil to encourage freezing during the winter.

CHEMICAL CONTROL

Fungicide types...

Understand the mode of action of fungicides...Fungicides are classified as either "protectant", "translaminar", or "systemic" based upon how they interact with the plant and fungus.

Protectant fungicides provide disease control by protecting the surface of the leaf or plant part with a coating of fungicide. For a protectant fungicide to properly work, it must be spread over the entire plant before the plant is exposed to the fungus. Protectant fungicides do not enter the plant, nor do they move within or on the plant, except for some redistribution downward in the plant canopy that may occur during irrigating or a rain storm. Chlorothalonil (Bravo) and the EBDC fungicides (Maneb, Dithane, Polyram, Penncozeb, Manzate) are examples of protectant fungicides.

Translaminar and systemic fungicides, on the other hand, actually penetrate and enter plant tissues after the chemical is applied. For example, the metalaxyl portion of Ridomil prepacks is a systemic fungicide. The fungicides (Tattoo C, Curzate, Acrobat, Tanos, etc.) behave somewhat differently. Ridomil, a chemical that was effective against earlier strains (US-1) of late blight, moved downward in the plant. These newer systemic chemicals are more limited in their movement and are translocated with the leaf and, to some extent, upward in the plant. Chemicals with this type of limited movement are referred to as "local or limited systemics" and the type of translocation is referred to as "translaminar".

Selecting a fungicide...

Included in this action plan is a list of fungicides (a.i.'s with examples by common name; pg 17) labeled for use on potatoes for controlling late blight. The fungicide selected is not as important as application coverage and timing as discussed below. However, the use of copper or tin fungicides alone is not recommended for controlling late blight. These products provide excellent control when used in combination with other fungicides. It should be noted that the copper and tin products are available for use by organic producers.

Colorado State University personnel will be keeping track of late blight strains that occur in Colorado. US-8 is the prevalent strain found currently in Colorado. Most late blight strains, including those found in Colorado are resistant to Ridomil. When Ridomil-sensitive late blight strains are present, applying Ridomil can be extremely effective for controlling late blight, however, Ridomil is not recommended for use in controlling late blight at this time in Colorado. The companion fungicide in Ridomil Gold is a protectant fungicide which is effective for controlling late blight. If still using applications of Ridomil for control of pink rot and *Pythium* leak, also consider the application of the companion fungicide in the prepack to be part of a protectant spray program for late blight. Most of the "limited systemic" fungicides such as the strobilurin fungicides usually include a protectant as either part of the fungicide pack or used in combination with these fungicides to reduce chance for resistance. Remember that chlorothalonil, triphenyltin hydroxide and EBDC fungicides have limits on the amount of active ingredient that can be applied per acre each season. **Carefully follow label directions to be certain that you are not applying more per season than is allowed!** Alternating fungicide classes is also a good practice, and may be necessary if these use limits are being approached.

Consider these factors when selecting and using an application method...

To ensure thorough and complete fungicide coverage, a necessity for controlling late blight, a fungicide may need to be applied up to two weeks prior to potatoes being exposed to late blight. Keep in mind that using early season protectant fungicides to control early blight should be factored in to any late blight control

program. Irrigation, application, frequency, and amount of water applied all influence fungicide redistribution in the canopy. More redistribution is required for air application, less for ground, and least is required for chemigation.

Fungicide label directions...Fungicides may be applied by ground rig, aircraft or chemigation. Check the label for application restrictions because some products may not be applied by air or chemigation. Always use the highest rates allowed regardless of application method or fungicide combination.

Field size, shape, tillage practices, and obstacles...Choosing an application method depends on many factors, including field size and shape, location of obstacles, irrigation system, and tillage practices. For example, fields with houses or tall trees along the edges may not be good candidates for aerial applications. It is also important to realize that an application method that works best for a disease affecting mainly the lower stems, such as white mold, may not provide the best control of a foliar disease such as late blight.

Availability of equipment...Product choice also influences application method because some products have limitations on how they may be applied. Another factor to seriously consider is whether you can apply a fungicide in a timely manner with a given method. A successful late blight management program, and this cannot be overemphasized, must include having a fungicide applied to the potato crop **before** late blight is seen in a field. If you plan on using air or ground application methods, be certain that the equipment will be available when it is needed.

Equipment must provide complete coverage and be timely...There has been a lot of discussion about the superiority of ground application compared to air or sprinkler applications in providing fungicide coverage of the entire canopy, yet each method has advantages and disadvantages. Regardless of the application method you choose, planning and management are required to ensure the best results. Using even the best ground sprayer will allow late blight to develop under favorable weather conditions for the disease if nozzles are plugged or strips are skipped between applications. No matter which application method is used, be sure to completely cover the crop leaving no skips or areas untreated, and apply the fungicide at the appropriate interval for the disease pressure in your area.

Application methods...

Ground application...Applications using a ground sprayer tend to be very effective in controlling late blight because the water volumes and pressures used provide good leaf coverage and penetration of fungicide into the canopy. Research at the University of Wisconsin found that hollow cone and extended range flat fan nozzles were superior to floodjet nozzles. Recalibrate the sprayer often, and replace nozzles that are under or over applying by more than 10 percent. Raise the boom height as the crop grows to maintain the proper overlap in spray pattern.

The main disadvantages of ground applications are the time required to cover large acreage and incompatibility with certain irrigation systems. Multiple trips through the field with a ground sprayer will also increase soil compaction, especially on heavy soils. During 1996, the University of Idaho documented only a one to three percent reduction in yield due to sprayer traffic in two fields in the Treasure Valley. This yield effect, however, should be factored into the cost of ground application when compared to air and sprinkler application methods.

Air application...Air applications deposit most of the fungicide on the top of the crop which is then redistributed into the lower canopy by irrigation water or precipitation. A minimum of five gallons of water per acre is required for adequate coverage. Remember, nozzle calibration is just as important for air applications as it is for ground applications.

One of the biggest problems with aerial application is untreated strips caused by inadequate overlap between passes. Skips can be avoided by marking spray passes with permanent flags and alternating spray passes on the flags and between flags on subsequent applications. Availability of planes for timely applications has occasionally been a problem in Colorado. Arrange for an applicator for the new season as early as possible. Work with the aerial applicator to identify field areas that cannot be treated due to obstacles (trees, power lines, houses, etc.). Treat these areas with a ground applicator to ensure proper coverage.

Sprinkler application...An advantage of using a sprinkler system for applying a fungicide is the system is already in place so you do not have to wait for equipment. However, applying fungicides through a sprinkler system tends to deposit lower levels of fungicide within the plant canopy. Therefore, it is especially important to use the highest labeled rate of fungicide to ensure an effective concentration on the leaves. Use appropriate chemigation equipment making sure the injection pump operates the entire set.

For any type of irrigation system, make sure the field is the same size as the system; i.e., no potatoes outside of the water coverage area. The uniformity of fungicide application is very dependent upon the uniformity of water distribution. Corners of fields irrigated with center pivot systems do not usually receive adequate fungicide coverage and should be sprayed with a ground applicator, or not planted to potatoes. It is easiest to verify water distribution prior to planting to avoid non-covered areas. For solid set, inject the fungicide during the last 15 minutes of the irrigation set, or make a separate application between irrigations. Make sure the fungicide has flushed out of the end nozzles before shutting off the system.

One of the main disadvantages of center pivot applications of fungicide is the huge volume of water applied with the chemical. Therefore, it is important to adjust the revolution time to the fastest setting so as to apply the least amount of water to the foliage. Always use the highest labeled rate when applying a fungicide through a sprinkler system.

When to apply a fungicide...

Initial applications...All potato fields should be sprayed with a protectant fungicide before row closure followed by a second application in seven to ten days. Whether additional applications are needed will depend on weather conditions and occurrence of late blight in any given region. In any case, these initial applications may be slightly earlier than is normal for control of early blight. These early applications treat the stems and lower canopy where late blight often begins once the vines close the rows and conditions within the canopy become more favorable for late blight. Early fungicide applications are recommended regardless of the forecasting model because of the chances of infections starting from local sources such as volunteers, cull piles, or infected seed stocks. These applications are especially important in the San Luis Valley since there is a high likelihood of late blight potential after the finds in 2007.

Growers are cautioned that predicting behavior of late blight in Colorado is based on only four years of experience in the San Luis Valley in the past 40+ years, and that occurrence was quite late in the growing season. Other growing areas of Colorado have had similar lack of experience. While this is quite positive for the potato industry as a whole over the past several years, it would be naive to think that the potential to late blight exposure is low. All potato-producing areas must be considered at risk for developing the disease any time the environmental conditions become favorable for late blight, particularly after row closure.

Applications up to late season...Rigorously scout for late blight and pay careful attention to weather conditions favoring late blight development; i.e., weather cooler and wetter than normal. After the first two fungicide

applications, if late blight is found in the area or weather conditions are conducive for disease development, then continue spraying protectant fungicides. A preventive attitude is very important when dealing with late blight. Attempting to "rescue" a field after late blight occurs is very likely to fail! If late blight is found in the field, use of the systemic and/or translaminar type fungicides is warranted and should be considered to hold the infection in check. Use of protectant fungicides for early protection makes it much more effective to control the disease spread in-field and out-of field. Be sure to follow label directions, rotate the various chemistries, and alternate a protectant type fungicide between applications of the systemic/translaminar fungicides or use in the mix as directed. It is vital to stay ahead of the late blight fungus with a well thought out fungicide spray program. It is important to remember that fungicides must be applied at intervals that maintain coverage on new leaves, especially when environmental conditions are conducive for late blight development.

Late season...Continue fungicide applications at intervals based on weather conditions and recommendations from Colorado State University or your crop care providers. Protectant fungicides may need to be applied even after vine dessication until all green vines are completely dead if late blight was present in the region or field. It is not recommended that a fungicide be applied as a tank mix with a vine killing agent. Early vine killing may be the best option for growers with out-of-control late blight infestations. **Remember, if you kill the potato plant, you kill the fungus growing on the plant!**

Recommendations to reduce late blight tuber rot...Season-long control of the late blight fungus on the vines (leaves and stems) is extremely important for reducing infection of tubers. Serious tuber late blight infections have occurred even when only small percentages of foliar blight were observed in the field. Follow recommendations above to reduce chances of tuber infection during harvest.

Materials Labeled for Use on Potatoes to Control Late Blight

Active Ingredient (Common Name)	Rate/Acre	Effectiveness				Action Mode			Rain Fast-ness	Mobility in Plant
		Leaf Blight	New Growing Point	Stem Blight	Tuber Blight	Protectant	Curative	Eradicant		
Cymoxyanil: (Curzate 60 DF)	1.25-1.5 lbs	++(+)	0	+(+)	0	++	++	+	++	Translaminar
Dimethomorph: (Acrobat MZ)	2.25 lbs	++(+)	0	+(+)	++	++(+)	+	++	++(+)	Translaminar
Propamocarb-HCL: (Tattoo C)	2.3 lbs	++(+)	+(+)	++	++	++(+)	++	++	+++	Systemic
Cyazofamid: (Ranman)	1.4 - 2.75 lbs a.i.	+++	0	+	+++[b]	+++	0	0	+++	Contact
Famoxadone & Cymoxyanil: (Tanos 50DF)	6.0-8.0 oz	++	0	+(+)	N/A	++	++	+	++	Contact
Fluazinam: (Omega)	5.5 floz	+++	0	+	++(+)	+++	0	0	++(+)	Contact
Zoxamide: (Gavel)	1.5-2.0 lbs	+++	0	+	++	+++	0	0	++(+)	Contact
Fenamidone: (Reason 500SC)	5.5-8.2 floz	++(+)	0	+(+)	++	++(+)	0	0	++	Translaminar
Dithiocarbamate:[a] (Maneb 80WP) (Dithane DF)	2.0 lbs 2.0 lbs	++	0	+	0	++	0	0	+(+)	Contact
Chlorothalonil: (Bravo Weatherstik)	1.5 lbs	++	0	(+)	0	++	0	0	++(+)	Contact
Copper: (Kocide 101)	4.0 lbs	+	0	+	0	+(+)	0	0	+	Contact
Triphenhyitin hydroxide: (Super Tin 80WP)	3.75 oz	++	0	+	++	++	0	0	++	Contact
Metalaxyl:[c] (Ridomil Gold EC)	2.0 pts	+++	++	++	N/A	++(+)	++(+)	++(+)	+++	Systemic
Strobilurins:[d] (Quadris-Opti) (Headline)	6.0-15.5 floz 6.0-12.0 floz	+++ +++	0 0	+ +	0 0	++ ++	+ +	0 0	+++ +++	Systemic & Translaminar
Difenoconazole (EB) **& Mandipropamid** (LB): (Revus Top) currently not labeled for CO	7.0 floz	+++	0	?	0	+++	+	0	+++	Translaminar

Notes: [a]Includes maneb, mancozeb, propineb, and metiram. [b]Based on limited data. [c]Consider sensitivity of LB isolate to Metalaxyl proir to use. [d]Always use strobilurin fungicides with a protectant added to mix to help in resistance management.

Key to ratings: 0 = no effect; + = reasonable effect; ++ = good effect; +++ = very good effect; N/A = not recommended for control of tuber blight. Before using any pesticides consult the product label for full details.

This list is not a recommendation for use nor does the listing include all products registered for controlling late blight.

Information about active ingredient effectiveness and properties was taken from the "Handbook of Potato Production, Improvement, and Postharvest Management", 2006, eds. J. Gopal & S.M. Paul Khurana, pp.293-94, table 8.2.

Examples of Fungicide Regimes if...

1) No late blight is found in the region...

Spray a protectant fungicide prior to row closure and follow with a second application within seven to ten days. Maintain your standard fungicide program for controlling early blight.

2) Late blight is found in the region, but not in your field...

Follow steps in #1. At the time of the late blight find in the region, begin to shorten intervals between fungicides and continue spraying through the season, until vines are dead.

3) Late blight is found in your field...

Follow steps in #2. At the time that the first foliar lesions are seen in your field, begin an aggressive program where protectant fungicides are alternated with "limited systemic" fungicides. Continue monitoring the field and maintain a very aggressive approach to control throughout the remainder of the season, paying special attention to the time just before and after vine dessication, when tuber infection is the greatest risk. Tin products should be incorporated into the fungicide rotation toward the end of the growing season to help reduce risk of tuber infection.

Remember, late blight is a serious threat to any potato crop, but it is only one of many diseases and problems which may show up in your potatoes. Always maintain an aggressive approach to controlling this disease without sacrificing good production practices and sound management strategies for your overall crop.

APPENDIX

Terms used in Discussing Late Blight

Aggressive - Used to describe the reaction of a late blight genotype (strain) on a potato, or other susceptible host. Aggressive genotypes produce more sporangia, cause larger leaf and stem lesions, and/or have a shorter latent period.

Asexual - Reproducing or producing spores (sporangia and zoospores) without mating (no sex).

Fungus - (plural, fungi) A microscopic plant lacking chlorophyll that may cause disease in higher plants such as potatoes and tomatoes.

Genotype - A population of late blight fungi with similar traits. Late blight fungal genotypes are designated using the letter "US" followed by a number (example; US-8).

Inoculum - Structures in the life cycle of the late blight fungus capable of infecting plants.

Latent period - The period from the time a late blight spore(s) infects a plant, but symptoms are not visible, to when the plant shows visible symptoms of the disease.

Lesion - Area on a leaf or stem showing symptoms of late blight.

Mating type - Term used to describe the "sexes" of late blight. Mating type is used rather than male and female because the two types are indistinguishable outside of the laboratory, but both mating types, referred to as A1 and A2, must be present for the late blight fungus to sexually reproduce.

Oospore - A thick walled structure capable of surviving unfavorable environmental conditions outside of a living host, produced from the sexual mating of A1 and A2 mating types. Usually considered rare in most potato producing areas in the U.S. and Canada.

Spore - A fungal structure containing one or more cells capable of reproducing, germinating and causing infection.

Sporangia - An asexual structure of the late blight fungus that can germinate directly or indirectly by producing zoospores. Sporangia can be carried in moist air, spreading the disease (see also zoospores). There are many reported cases of the spores traveling long distances (up to 50 miles or more) under conducive environmental conditions from an infected field to another un-infected field to cause infection.

Strain - Genotype.

Zoospores - Spores produced inside a sporangium (plural, sporangia) if environmental conditions are correct, that have limited locomotive (swimming) ability in water, and are capable of infecting a susceptible host with late blight. Zoospores can be carried in water for great distances.

Procedures for Late Blight Samples

Colorado State University will diagnose both leaf and tuber samples for late blight. There will be no charge unless laboratory analysis is requested for confirmation ($25.00/sample). Please observe the following guidelines for collecting and submitting samples.

Leaf and stem samples

You will need zip-lock or plastic bags, paper towels, distilled or well water (tap water may contain chlorine which will inhibit the growth of the fungus), labels, lead pencils and 5% Chlorox.

1) Potato leaf (the entire leaf and not the leaflet) suspected to have late blight should be removed from the plant. Collect leaves that show dark brown or black lesions, sometimes with a yellow margin or water-soaked halo. Select, if possible, leaves that show white fungal growth on the underside. Leaves should not be completely decayed, but should have green tissue left to allow the fungus to continue to grow.

NOTE: When looking for symptoms, do not mistake symptoms that look similar to late blight. Early blight usually has concentric rings in the affected areas with the lesion bounded by the leaf veins, white mold has lumps of cottony growth or sclerotia, bacterial soft rot may appear water-soaked, wet and slimy, and wind burn or maturity is usually very dry without the characteristic margin or halo.

2) What is an adequate sample? In case of a spore-bearing fungus such as *Phytophthora infestans*, positive identification is possible even from a very small piece of plant material. In a potato field collect three or four leaves (not leaflets) per location and a total of four locations in the field.

3) Place the entire leaf or leaves from each location between sheets of dampened (not wet) paper towels. Roll or fold the paper towel and then place into a sealed plastic bag and hold in a cool location. Samples should be hand delivered within 12 hours of collection. If this is not possible or they are to be sent in the mail, place the samples in a refrigerator. Mail should be overnight delivery only.

4) Place a label (written using a lead pencil) **INSIDE** the bag with the following information...

Name of grower or farm
Field location
Cultivar
Date collected
Phone or fax number or other contact information

5) It is recommended that you deliver the sample in person to the nearest Colorado State University location or mail overnight. Avoid weekend mailings.

6) If you plan to walk into other potato fields directly after taking the samples, disinfect your boots with 5% Chlorox or use disposable protective covers to avoid spreading the fungus.

Tuber samples

- Collect a representative sample of tubers suspected to have late blight from several areas of the storage (minimum of ten tubers, maximum of twenty). Collect the tubers that are showing signs of decay, but not those where the decay has progressed to the extent that more than 50% of the tuber has rotted. Tubers that are severely decayed often have secondary rot organisms present that can "mask" the symptoms of late blight on tubers and greatly complicate the diagnosis.

- Carefully wrap the tubers in dry paper towels and place them into a paper bag. The paper towels should help absorb some of the moisture and prevent the paper bag from falling apart. It is suggested that the paper bag should then be placed into a leak-proof container such as a plastic bucket or plastic sweater box. **Never enclose the tubers in plastic!**

- Place a label (written in a lead pencil) **INSIDE** the bag with the same information as requested for the leaf samples.

- Submit the samples as soon as possible to the nearest Colorado State University laboratory. If possible, submit samples within 24 hours of collection. If samples must be held overnight, place them in a cool dry location or in the refrigerator. Please call before submitting samples.

Laboratory locations and contact personnel are listed below...

In the San Luis Valley...

San Luis Valley Research Center, 0249 East Rd. 9 North, Center, CO 81125
Attention: Dr. Robert Davidson or Ms. Rue Snell
(719) 754-3496 ext. 15 (Rob) or ext. 18 (Rue), FAX (719) 754-2619

In other areas of Colorado...

Colorado State University, Dept. of Bioagricultural Sciences and Pest Management, E210 Plant Sciences, Fort Collins, CO 80523
Attention: Dr. Howard Schwartz or Mark McMillan
(970) 491-6987 or (970) 491-7846

Colorado State University, Dept. of Bioagricultural Sciences and Pest Management, Plant Disease Clinic, E20 Plant Sciences, Fort Collins, CO 80523
Attention: Dr. Ned Tisserat or Ms. Tamela Blunt
(970) 491-6950

Management of Volunteer Potatoes

- Volunteers are potatoes left over from harvest that sprout the following year. They can serve as hosts for late blight and other diseases that spread to healthy potato crops.

- Volunteer potatoes are very difficult to control. The most effective strategies require an integrated approach.

- Let cold winter temperatures freeze potatoes remaining in the field after harvest. Deep cultivations should be avoided in the fall since this buries tubers and protects them from freezing temperatures.

- Three to four cultivations when volunteer potatoes are at the 9 to 11 leaf stage are very effective for volunteer control, particularly when following herbicide use.

- Short season potato cultivars have fewer volunteers because fewer are left behind during harvest and they tend to decay easily when left in the field.

- Choose rotation crops that are strong, healthy competitors (alfalfa, canola and small grains) or utilize effective herbicide/cultivation practices. Avoid planting potatoes on potatoes as this makes controlling volunteers almost impossible and is a bad practice when considering many other disease problems.

- Herbicides currently used in rotation crops are not very good when used alone for killing volunteer potatoes. Even glyphosate (Roundup™) herbicide will not kill small volunteer potatoes which will likely emerge again within a few weeks. A combination of herbicide and repeated cultivations are presently the most effective for control of volunteer potatoes in rotation crops.

- Fumigation of the soil at higher application rates helps to reduce volunteer potatoes.

Disposal of Cull Potatoes

- Vine and tuber waste debris are hosts for late blight and are primary inoculum for both early and mid-season outbreaks of this disease. *Phytophthora* spores can be massively produced on leaves, vines, sprouts and tubers in a cull pile. All cull potato material must be routinely discarded to help prevent spore production and seasonal spread of late blight.

- Currently only the San Luis Valley region of Colorado is under a cull potato management law. This management law is undergoing revision, but under its present form, the law reads that all cull potatoes (waste, off grade and volunteer potatoes) shall be destroyed prior to potato plant emergence or no later than June 15th of any year, and thereafter, within forty-eight (48) hours utilizing one of the methods set forth below...
    - A. Processing;
    - B. Utilizing for livestock feed. The culls shall be consumed within forty eight (48) hours unless covered with a tarp;
    - C. Buried, if lawful under applicable statutes, rules or ordinances;
    - D. Spread uniformly on the soil surface to a depth of no greater than three inches so that the culls are made none viable by freezing or dessication;
    - E. Treated pursuant to label directions with a pesticide effective for the destruction of volunteer potato plants.

Disposal options

Field Spreading

- Cull potatoes may be spread in a thin layer on fields during the late fall and early winter.
- Exposure to thorough freezing prevents tubers and vines from serving as live hosts for late blight.
- The depth of spreading should be no more than two potato layers deep (6").
- Do not cultivate areas spread with cull potatoes until they are thoroughly and completely frozen.
- Culls should not be spread on fields intended for potato production because of the danger of introducing weeds, nematodes and soil borne diseases.
- Field spreading should not be done in late winter during years when the air temperatures are not cold enough to cause freeze damage or after the spring cut-off date requiring daily disposal of culls.

Burial

- This disposal method can be used any season of the year.
- Trenches filled with cull material should be covered with a minimum of 18" of clean soil to prevent sprouts from emerging.
- The deeper the cull tubers are buried, the less likely sprouts will be able to emerge.
- Potato tare dirt is not an acceptable cover because of the risk that small pieces of tuber may be mixed with the soil.
- Cull material in trenches must be covered daily after the spring cut-off date.

Livestock Feed

- Cull and waste potatoes can be utilized as a feed for livestock during the late fall and winter. Feeding cull potatoes in the spring or summer is not recommended unless all exposed culls are **completely** consumed each day!
- Large cull potatoes should be chopped before feeding to cattle to avoid choking.

- Cull potatoes that are field spread are still good feed after natural freeze-drying occurs. Do not spread onto deep soft snow which may provide insulation against freezing.
- Culls should not be spread on fields intended for potato production because of the danger of introducing weeds, nematodes and soil borne diseases. Manure produced by livestock fed with cull potatoes should also not be spread onto fields intended for potato production for similar reasons.
- Sprouting must not occur in culls spread onto fields or placed within feed bunks.

Composting

- Potatoes can be placed in large composting piles during the late fall and winter. Compost piles started during the summer may have small tubers on the outer surface of the pile that can sprout or serve as a host for late blight.
- The temperatures within a properly managed compost pile not only speeds decay of tuber tissue, but may also help to directly kill the late blight fungus.
- Compost piles must be turned and mixed routinely, and may require special equipment for larger piles.
- **A poorly managed compost operation is nothing more than a cull pile in disguise.**

Management during seed cutting

Slivers and discarded tubers generated during the cutting operation can sprout quickly under the right conditions. Tare dirt and discarded potatoes are cull potato debris and should be properly managed to prevent this material from hosting the late blight fungus.

Monitoring cull disposal sites

All cull disposal sites should be closely monitored the next spring to make sure that volunteer plants are not emerging. The Colorado Department of Agriculture is responsible for verifying that cull pile disposal sites are properly managed and that deadlines are being met.

Broad spectrum herbicides typically are slow to kill vines or emerging sprouts on cull potatoes, or only temporarily suppress vine growth. Other disposal methods are available that are more effective than herbicides.

REQUIREMENTS FOR IMPORTING SEED POTATOES INTO THE SAN LUIS VALLEY OF COLORADO

The primary means by which late blight could be introduced into the San Luis Valley is through contaminated seed potatoes. For this reason, a quarantine was declared against the importation of seed potatoes, unless such seed potatoes are certified and inspected as late blight free. The terms and conditions of this quarantine are based on the best knowledge of late blight to date. Full compliance with the terms and conditions of the quarantine, however, does not guarantee that the late blight fungus will not be introduced into the San Luis Valley, on imported seed potatoes. Therefore, every effort must be made to avoid planting seed potatoes not produced within the San Luis Valley. Should it become essential to import seed potatoes, the following requirements must be met. In order to facilitate the reinspection process required for each load of seed, we strongly recommend that regulatory officials in the San Luis Valley be notified in advance of all incoming shipments.

The following requirements are pursuant to the Colorado Pest Control Act §35-4-110, C.R.C. (1995) and HB96-1018.

1. Imported seed potatoes must be Certified and accompanied by official Certification documents from the state or province of origin.

2. Each shipment of seed potatoes must be accompanied by an inspection certificate that indicates that no late blight was present in the field during growing of the crop or at the time of loading the seed potatoes for shipment.

3. Each shipment of seed potatoes must be accompanied by a document which shows proof that a representative sample of tubers from the load(s) was tested for late blight.

4. The following late blight tuber test is to be performed well in advance of shipping seed potatoes into the San Luis Valley.

   * Truck load shipments. A representative sample of 400 tubers, ideally in the 4 to 10 ounce size range, must be collected from the seed lot intended for shipment.

   * Greenhouse minitubers. A representative sample of 100 minitubers, in the medium size range, must be collected from each seed lot or greenhouse crop from which seed is intended to be shipped into the San Luis Valley.

   * Small tuber samples for research. Small shipments of tubers (not to exceed 50 lbs) that are intended for research must be tested for late blight at the 20 percent level. For example, from a 50 pound sample of tubers a 10 pound sample must be submitted for testing.

* Each tuber sample must be held at room temperature (65-75°) in the dark under high relative humidity (90-95%) for 21 days.

* After 21 days each tuber in the sample must be individually washed and carefully examined by a qualified person for suspect late blight lesions. Tubers exhibiting lesions should be sliced apart, incubated at high humidity and then examined under a microscope.

* All disease observed in the sample must be diagnosed as to the causal agent. If *Phytophthora infestans* is confirmed in any portion of the sample, the seed lot cannot be shipped into the San Luis Valley.

* Upon completion of this test, fax a copy of the results to the San Luis Valley Inspection office at 719-852-0187.

5. If the inspection certificate accompanying a load indicates that late blight was present during growing or loading, or no statement is made on the certificate concerning the presence or absence of late blight, the load(s) to which said certificate pertains shall not be unloaded, and, pursuant to § 35-4-109, shall be removed from the state within forty-eight (48) hours or shall be destroyed by the Commissioner.

6. Any load(s) which are not accompanied by an inspection certificate shall not be unloaded, and, if a certificate cannot be produced within forty-eight (48) hours, pursuant to § 35-4-109, shall be removed from the state within forty-eight (48) hours or shall be destroyed by the Commissioner.

7. If the inspection certificate indicates that no late blight was present during the growing, loading, or testing, the load(s) to which said certificate pertains shall be reinspected during the unloading process. Shipments of greenhouse minitubers intended as Certified seed are exempt from reinspection. Random sampling of the load shall be taken and any tubers showing symptoms of late blight shall be tested. Any load(s) showing symptoms of late blight shall be placed in a bin and held at the place where reinspection occurred, or, they shall be placed in a truck owned by the receiver of said load(s) and held at the place where reinspection occurred, pending results of testing. If late blight is confirmed by testing, the load(s) must be removed from the state or destroyed within seventy-two (72) hours.

Questions regarding the shipment of seed potatoes into the San Luis Valley should be directed to Colorado Department of Agriculture, Plant Industry Division, Monte Vista office, 719-852-3606; FAX 719-852-0187.

Late blight foliar symptoms as seen in 2007

Figure A:
Hot spot

Figure B:
Late Blight symptoms

Leaf and stem lesions,
Growing point

Figure C:
Whole plant symptoms