Managing Potato Production for Optimal Plant Health

RANDALL C. ROWE
Department of Plant Pathology
Ohio Agricultural Research
and Development Center
Ohio State University, Wooster

Potato disease management begins long before the crop is planted, with programs for the development of disease-free seed stock, and extends past harvest to include maintenance of storage conditions for control of postharvest decay. This article presents an overview of management practices necessary at each stage of the production cycle to protect the crop from disease. Most strategies are applicable generally, but a few vary regionally.

Using certified seed

Use of certified seed is the first step in production of a healthy potato crop. The development of state-regulated programs for production of certified disease-free seed potatoes has been a major factor in controlling virus diseases (especially leaf roll and those caused by potato viruses A, X, and Y), the spindle tuber viroid, and potato ring rot (*Corynebacterium sepedonicum*). Most states use a complete "flush out" system whereby each generation of seed stock is used to produce only the next lower classification of seed potatoes. Production begins with reproduction of disease-free nuclear stock in the field at a remote location, often a state-operated farm, for three or four generations to increase stocks sufficiently for release to certified seed potato growers. Extensive testing for pathogen contamination is done on each generation, and rigorous disease tolerances are maintained. Progeny from this process are then sold to seed growers who produce "foundation" and "certified" seed potatoes for sale to commercial growers. Field inspections, serological assays, and winter "grow-out" tests in Florida or California are part of most certification programs.

The recent introduction of disease-free tissue culture technology into nuclear seed stock production has added a new dimension to many state programs. Multiplying plants in vitro through aseptic stem cuttings eliminates 2–3 years of field production time for nuclear stocks, minimizing the exposure of nuclear stock material to potential pathogen contamination. The result of these programs is a continuous supply of high-quality seed potatoes that are certified for varietal purity and adherence to specific tolerances for pathogen contamination.

Selecting cultivars and preparing sites

Several decisions with implications for plant health management must be made by potato growers before planting. Cultivar selection is of primary importance. Because potato cultivars have been bred with horticultural and processing qualities as the main consideration, incorporation of disease resistance has not been a major criterion and resistant cultivars are not generally available. However, potato cultivars do vary in susceptibility to diseases such as scab (*Streptomyces scabies*), Verticillium wilt (*V. dahliae* and *V. albo-atrum*), and late blight (*Phytophthora infestans*) and to physiological disorders such as hollow heart and internal necrosis. Avoidance of highly susceptible cultivars is important, particularly when a grower anticipates a specific disease problem on the basis of experience. Horticultural considerations, however, often outweigh this factor.

Site selection and preparation are also significant in disease management. Adequate soil drainage is critical to avoid preharvest decay by tuber-rotting organisms favored by wet soils. A 2- to 3-year crop rotation scheme is advisable to minimize populations of soilborne pathogens. Rotation alone will not control most soilborne pathogens but is an important disease management component and also has significant advantages in control of weed and soil insect pests and in management of soil structure and fertility. Maintaining the pH of potato-production soil below 5.5 for scab control has long been recommended. Although acid-tolerant strains of *S. scabies* have been reported, this recommendation is still generally valid. The addition of animal manure to soil used for potato production may greatly aggravate a scab problem and should be avoided.

The decision to fumigate soil before planting depends on the expected market value of the crop and the anticipated losses from certain soilborne pathogens. Although expensive, fumigants are effective against nematodes and Verticillium wilt. Fall or spring shanking of volatile fumigants is used in some areas; in areas with light-textured soils, applying water-soluble metam-sodium through sprinkler irrigation equipment is gaining popularity. Application of granular insecticides/nematicides such as aldicarb at planting or after emergence may be a useful alternative to fumigation for nematode control.

The amount of nitrogen needed is another consideration. Insufficient nitrogen during tuberization can increase susceptibility of foliage to early blight (*Alternaria solani*) and hasten the development of Verticillium wilt. Excess nitrogen, on the other hand, can produce an extensive overgrowth of foliage, resulting in a protected, moist microclimate at the soil level, especially under sprinkler irrigation. These conditions favor development of bacterial soft rot and blackleg (*Erwinia carotovora*) and Sclerotinia rot (*S. sclerotiorum*) of the lower stems, as well as gray mold (*Botrytis cinerea*) and late blight, all of which can cause extensive vine death.

Handling and storing seed potatoes

Proper handling of seed potatoes before planting is an essential step in disease management. Seed potatoes are trucked from northern seed growers to commercial farms in late winter, and frost injury in transit is common. Growers should inspect seed on arrival and reject any lot with visible frost injury. Fusarium dry rot (*Fusarium* spp.) is another problem growers must check for in a new shipment of seed potatoes. Thiabendazole treatment of seed potatoes before shipment has been useful in controlling dry rot, but new infections may begin at wounds that occur during handling and shipping.

Growers must often store seed potatoes for 6–8 weeks before planting. Seed in burlap sacks should not be stored higher than two pallets, and plenty of space must be allowed for aeration. Bulk shipment of seed potatoes is becoming more common because of efficiencies in handling and bulk storage in bins with forced-air ventilation. In either case, all storage areas should be disinfested before receipt of seed potatoes to minimize contamination from pathogens associated with previous crop residues. Seed should be stored at 38–45 F but warmed to 55–60 F before the cutting operation is begun.

Cutting of seed pieces from whole "A-size" tubers is a prime point in the

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production cycle for spread of tuber-borne pathogens, particularly ring rot and soft rot bacteria. Seed cutting equipment should be thoroughly disinfested before use and again between each seed lot to avoid potential cross-contamination. After cutting, seed pieces should be dusted with a fungicide formulated for that purpose. Studies in Ohio have shown that emergence after seed treatment is not improved every year, but the practice is beneficial in years when weather conditions are unfavorable for rapid emergence during the 4–6 weeks after planting. After fungicide treatment, cut seed should be held at 55 F with good air movement through the seed-piece pile to hasten the healing process. Some growers cut seed pieces and plant immediately. That works well if soil temperature is in the 55–65 F range so healing can proceed rapidly in the soil. In cold, wet soil, unhealed seed pieces are more likely to rot before germination. The use of uncut, small "B-size" seed tubers avoids the risks of seed cutting and eliminates the need for healing procedures. Higher cost and horticultural considerations, however, often preclude the use of whole seed.

Planting

The planting operation also has disease management implications, not the least of which is the planting equipment. The pick-type planter, which is standard in the industry, jabs seed pieces with a series of picks on a rotating disk and drops them into a chute over the furrow. After puncturing an infected seed piece, a contaminated pick can spread tuber-borne bacteria, such as those causing ring rot and blackleg, to the next 40–50 seed pieces. Cup planters, in which the seed pieces are carried in small cups and not punctured, can eliminate this risk.

To promote quick emergence, planting should be delayed until soil temperature warms to 55–60 F. Planting in cold soil leads to slow emergence and usually poorer stands because seed pieces decay in the soil. Depth of planting is also a factor in emergence. Shallow planting, i.e., at 2–3 in. rather than 5–6 in., results in faster emergence and less stand loss to Rhizoctonia stem canker. *Rhizoctonia solani* attacks emerging sprouts and may girdle and kill them before they emerge. After emergence, stems are much less susceptible.

Controlling foliar diseases

During crop development, two foliar diseases are of primary importance and must be managed with fungicides. Potato late blight has been a problem for potato growers since it caused the Irish potato famine in the mid-1840s. *P. infestans* coevolved with potatoes in South America and is an obligate parasite. In the United States and Canada, the fungus must survive the winter as mycelium in infested potato tubers left in soil or cull piles or be reintroduced in contaminated seed potatoes. Sporangia are produced during periods of cool, damp weather, and foliage is infected under these conditions. Although late blight does not appear in a given field or area every year, its destructive potential demands that growers protect their crops against it.

Early blight is present wherever potatoes are grown. The fungus is a good saprophyte and survives in infested plant debris in or on the soil surface, forming spores over a fairly wide range of temperatures. As potato foliage matures, susceptibility to *A. solani* increases. "Early blight" is thus a misnomer, as symptoms rarely develop until after flowering.

Both diseases are managed by timely application of protectant fungicides. Mancozeb and chlorothalonil are the most commonly used and must be applied on a weekly basis by either aerial or ground equipment. Thorough coverage of plant surfaces is essential, as control is protective. A number of forecasting systems have been developed for late blight to aid growers in scheduling fungicide applications. BLITECAST, the most commonly used system, is based on measuring rainfall and intervals of high humidity and calculating blight-favorable periods. Recommendations are then made for spraying at 4-, 7-, or 10-day intervals.

The foliar protectants used to control both diseases work well, but problems arise when weather conditions favoring disease development make fungicide application impossible. Introduction of the systemic fungicide metalaxyl has provided a new tool for late blight management. Metalaxyl is effective when applied on a 14-day schedule, giving a longer period of protection, and can be used as a postinfection curative treatment, eliminating established infections. Furthermore, because of its systemic properties, metalaxyl protects tubers from infection by *P. infestans* and certain other soilborne fungi. Metalaxyl is especially useful in conjunction with forecasting systems because growers can respond to infection periods that have already occurred with a treatment that has curative "kickback" action.

Two major limitations to metalaxyl are lack of efficacy against early blight and potential development of tolerant strains of *P. infestans*. Because of these constraints, growers continue to depend on the standard protectant fungicides and apply metalaxyl only once or twice a season or use it as an eradicant after late blight appears.

Managing diseases during crop production

Although insects are significant pests in potato production and merit careful consideration in any management program, insect control measures are beyond the scope of this article. Alate aphids and leafhoppers are closely involved in potato plant health because of their role as virus vectors, and even though potato virus diseases are controlled primarily through seed certification programs, judicious use of foliar insecticides to manage populations of these insect pests is also necessary.

Another major problem during the growing period is potato early dying (PED) disease. Vines die 3–6 weeks earlier than expected, primarily because of systemic infection by the soil fungus *V. dahliae*. Research has shown that other pathogens, such as the root lesion nematode (*Pratylenchus penetrans*) and soft rot bacteria (*Erwinia* spp.), are also involved. In dealing with this disease, growers do not have many viable options. PED usually develops gradually over a number of years, resulting in slowly declining yields. Crop rotation, although helpful in minimizing *Verticillium* populations in soil, is not in itself satisfactory. Host resistance to *V. dahliae* is not available, but certain highly susceptible cultivars should be avoided if PED is an expected problem. Although expensive, soil fumigation has become widely accepted in some areas for controlling PED. At present, growers must base the decision to fumigate on experience. Research is under way to develop forecasting systems for PED on the basis of pathogen populations before planting. Information provided by such systems would allow growers to make more precise management decisions concerning not only fumigation but also field and cultivar selection and fertility.

Certain cultural practices during the growing season impact directly on disease management. Hilling—cultivation whereby soil is thrown over the bases of the vines—is done primarily to protect tubers from sunlight that results in chlorophyll development. Hilling can also protect tubers from late blight infection occurring when *P. infestans* sporangia wash from leaves into cracks in the soil and come in contact with tubers. Burying the tubers 4–6 in. below the soil surface provides an effective barrier to infection.

Irrigation scheduling involves complex management decisions with significant cultural impacts on potato production. Water availability also impacts on development of such diseases as scab and PED. Moisture stress during tuberization promotes scab development and hastens the onset of PED symptoms. Overirrigation may favor development of foliar diseases, especially late blight and blackleg. Uneven moisture can aggravate abiotic tuber disorders such as hollow heart and second growth.

Harvesting

Harvesting the potato crop involves a number of management decisions with plant health implications. The first step in the harvest process is usually application of a herbicide to kill the vines. If insect and disease pests are managed properly and fertility is kept optimal, vines are usually still vigorous at harvesttime and must be killed with chemicals. Vines must be dead for at least 1–2 weeks before harvest to assure that tuber skins are mature, thus minimizing harvest injury. Harvest wounds on tubers are the major entrance sites for soft rot bacteria and Fusarium dry rot pathogens. Also, if vines are not dead, viable *P. infestans* sporangia remaining on green foliage could be spread to tubers during harvest and cause infection during storage.

Steps must be taken during harvest to minimize bruising and wounding of tubers that could lead to storage decay. If tuber pulp temperature is below 50 F, harvest should be postponed until warmer weather to avoid excessive shatter bruise. Primary harvester chains should be operated to maintain a cushion of soil as far up the chains as possible. Chains should be completely filled with potato tubers to avoid injury due to bouncing and rolling. If yield is insufficient to fill the chains, growers should consider use of a windrower in conjunction with a two-row harvester so that four rows will go over the chains at once. All chain surfaces should be rubber-covered and the machinery adjusted so that tubers never fall more than 6 in.

Grading and storing

Grading into storage should be considered, especially if the amount of tuber rot in the field was significant. Eliminating so-called leakers on the conveyor line helps establish a healthy pile for winter storage. To prevent Fusarium dry rot during storage, many growers mist thiabendazole over the tubers as they fall onto the bin piler. As potatoes are piled for storage, the bin piler should be operated so that tubers fall no more than 6 in. and do not roll excessively. To avoid pressure bruises, tubers should not be piled more than 15–20 ft deep.

Regardless of precautions, some harvest injury will occur, and a curing period is mandatory to promote suberization of wounds on tuber surfaces. Potato storage facilities are designed to provide forced-air movement up through the pile. During the curing period, humid air (95% relative humidity) at 55–60 F must be moved constantly through the pile for 1–3 weeks. The storage environment must be monitored carefully, however, to avoid formation of free moisture on tuber surfaces. This can result in anaerobic conditions inside the tuber, inhibiting suberization and favoring the development of some soft rot bacteria.

Once wound suberization has occurred, storage temperature of fresh-market potatoes can be lowered to 38–40 F, where development of tuber pathogens is greatly retarded. With processing potatoes, however, storage temperature must be maintained slightly higher, at 45–55 F, depending on cultivar and type of processing, to avoid sugar development. This makes storage for processing, especially chipping, more difficult because tuber rot can proceed much faster at these temperatures. Air movement through the pile must supply sufficient oxygen for tuber respiration, as oxygen starvation can result in development of black heart. Humidity must be kept above 90% to prevent excessive dehydration, yet free water must not form on the tubers. Growers should monitor the pile closely for wet spots, slumping areas, and unpleasant odors—signs of decay within the pile. If any of these are detected, humidity in the forced air should be lowered, the pile opened, and potatoes graded and marketed quickly.

Infected tubers must be disposed of, with future crops in mind. Under no circumstances should cull potatoes be piled outside. Cull piles are notorious sources of late blight sporangia that form in the spring on sprouts of surviving tubers. During the fall and winter in northern areas where freezing is assured, tubers can be safely spread sparingly on fields that will not be used for potato production the next year. Otherwise, cull tubers should be buried at least 6 ft deep or taken to a landfill.

Before potatoes are removed from storage for marketing, the temperature should be slowly raised until tuber pulp temperature is above 50 F. Shatter bruise or internal blackspot may result if potatoes are cold when handled. Many fresh-market growers wash tubers before packing; these must be thoroughly dried before bagging to avoid soft rot development during the marketing process.

Ten principles

The important decisions at each stage of the production cycle can be summarized in the following 10 principles of potato plant health management:

1. Plant only certified disease-free seed potatoes.

2. Select and prepare planting sites and choose cultivars with disease management in mind.

3. Handle and plant seed potatoes to ensure rapid emergence.

4. Protect developing foliage with fungicides.

5. Manage the crop to minimize opportunities for disease development.

6. Kill vines before harvest.

7. Operate harvest equipment to minimize tuber injury.

8. Cure tubers in storage to heal wounds.

9. Manage storage conditions to minimize postharvest decay.

10. Warm potatoes before handling and dry before packing.

Incorporation of these practices into the total production scheme should result in optimal health of the potato crop.