Crop Profile for Potatoes in Minnesota

Prepared: July, 2002

General Production Information

Minnesota ranked 7th nationally in potato production in 2000 when Minnesota growers harvested 59,000 of 66,000 planted acres (1,3). The 90% harvest rate in 2000 compares favorably to 1999 when 75% of the 70,000 planted acres were harvested. Total yield for the 2000 growing season was 21-million hundred weight (360 cwt/Ac), worth $5.25/cwt, providing a total crop value of $111 million in 2000 (1).

Production Regions

The largest potato producing regions, or districts, in Minnesota are found in the central and northwestern regions of the state. The central district, including Sherburne, Morrison and Todd counties, planted 19,100 acres (18,400 ac. harvested) and produced 7.9 million hundred-weight in 2000, 37% of the statewide total for 2000. The northwestern district, including Polk, Clay, Kittson, Marshall and Red Lake counties, planted 23,900 acres (19,600 ac. harvested) and produced 4.1 million hundred-weight in 2000, 19% of the statewide total for during 2000 (1,4).

Overview of Potato Types Grown in Minnesota

The three major types of potatoes grown in Minnesota are white, russet, and red potatoes. White potatoes make up approximately 46% of the annual crop and are generally destined for processing, specifically potato chip production. Russets account for approximately 37% of the annual crop and are processed to make French fries and hash browns. Red potatoes, and a small number of other less common varieties, are destined for fresh market sale and constitute the final 17% of the crop (5).

Cultural Practices

Planting: begins in late April after soil temperatures reach a minimum of 45° F at planting depth, 3-4 inches beneath the surface, and is usually finished by the end of May (20). Ideal soil temperatures are 55-60° F, which promote fast growth while minimizing decay in the soil (16). Rows are typically spaced at 32-36 inches and seed pieces are planted 8-16 inches apart within rows, depending on variety (2). Seed

potatoes are warmed slowly to 50-55° F for several days before handling and cutting and after cutting may be planted immediately or stored at the same temperatures for 3-5 days with good air circulation and high humidity. Fungicide treatment can be used to reduce seed piece decay in the soil. While fertile, fine to medium textured soils are appropriate for potato production, ideal soils are sandy-loam textured. Peat and muck soils can also be used if well-drained and amended with fertilizer (2,20).

Irrigation: A significant portion of Minnesota potato acreage is irrigated. It is important that plants receive a constant supply of water during tuber formation and growth as moisture stress can reduce both yield and quality of the crop. Many growers utilize irrigation scheduling programs included with the Wisdom software package (2).

Weed control: Weed control practices involve the application of herbicides in addition to cultivation. Cultivation and herbicide use are critical to keeping weed pressure down two-three weeks after planting. Hilling is another effective weed control method. Combined with herbicide applications, hilling potatoes, when properly timed, can optimize weed control. Most of the herbicides are applied at emergence during the first hilling. Additional post-emergent herbicide applications may be applied as needed (2).

Insect control: numerous insects will feed on potato foliage or tubers. Some insects, specifically aphids and leafhoppers, vector disease pathogens that affect both yield and quality of potatoes.

Dessicants/Harvest: the use of desicants allows the harvesting of potatoes to progress rapidly. Desicate II, Paraquat, Reglone and Defol 5L are also registered as vine desiccants in Minnesota (19). Where vine growth is dense, a second application of specific products may be made. All products should be used in accordance with their labels. Potatoes are harvested roughly 90 days after planting, beginning in late August and continuing through October (1,5). Tubers are dug after vines are completely desiccated - usually 14-21 days post-treatment. This is done to reduce tuber infection by early and late blights and to allow the skin to set before harvest to avoid wounding during the harvest process.

Curing/Storage: Potatoes are cured while in storage. Curing promotes suberization (the build-up of a waxy, water impervious layer) and prolongs storability. Potatoes are cured at 50-55° F and a relative humidity of 90-95% for 2-4 weeks following harvest. After curing, tubers are prepared for long-term storage by reducing storage temperatures 1° F every 5-7 days to prevent reducing sugars to accumulate. Relative humidity remains at 90-95% during this period. Potatoes grown for seed or fresh market use are stored long-term at 38° F while those that will become fries are stored at 45° F and those used for chipping at 50-55° F. Potatoes that will be stored long-term require a sprout inhibitor be applied either in the field or once in storage, after tubers have been cured. Before potatoes are removed from storage they are gradually warmed to 55-65° F for 2-3 weeks (2).

Insect Pests

Major (annual) pests of potatoes:

Colorado potato beetle (*Leptinotarsa decemlineata*)

The Colorado potato beetle (CPB) is the most common and destructive insect pest of potatoes. Both the larvae and adult will feed on foliage, and if left unmanaged, can completely defoliate a plant. Severe defoliation will impair tuber development (13,21).

Adults are large, robust yellow-orange beetles with black stripes. They overwinter in the soil as adults at depths of 8-10 inches. Emerging from the soil in the spring to mate, females lay clusters of yellow eggs on the undersides of leaves. These eggs hatch within 2 weeks of being deposited, depending on air temperature. Larvae are initially brick red with black heads and have two rows of black dots along their sides. The larvae undergo four molts, growing progressively larger and turning a paler shade of red-orange after each successive molt. Commonly referred to as "pigs", larvae tend to feed in groups or clusters on the plants on which they originated. Fourth (terminal) instar larvae drop to the soil where they pupate for 2-3 weeks. Upon emergence, adults will either move to the field edge to overwinter, or begin feeding voraciously, mate, and lay eggs before burrowing into the soil to overwinter (10,12,13,14,21).

Control options: Crop rotation is an effective method to decrease crop exposure to CPB. The current year's potato crop should be planted as far as possible from the prior year's crop. Since adult beetles cannot fly unless temperatures exceed 70° F (early season temperatures rarely exceed 70° F), beetles walk rather than fly to nearby potato fields. Increased distance between potato fields helps to reduce and/or delay the arrival of CPB in current year potatoes (14,21).

Insecticides are most effective against small, first or second instar larvae. Although third and fourth instars cause the most damage via defoliation, the later instars can be very difficult to control with insecticides. Control options that focus on the first generation of CPB helps to lower populations of "summer adults" that are difficult to control and which are responsible for extensive defoliation (6,7,9,14,21).

CPB has developed resistance to many insecticides. Growers should carefully select and rotate insecticide classes to decrease the onset of chemical resistance. Depending on the growth stage, potatoes can tolerate some defoliation before yield is affected. To protect the efficacy of currently available insecticides, applications are recommended only once the following thresholds have been exceeded (14,19):

PLANT STAGE	ALLOWABLE DEFOLIATION	PEST STAGE
Preflowering	20-30%	Overwintering adults and larvae
Flowering	5-10%	Larvae and summer adults
Tuber formation	30%	Summer adults and larvae

Potato leafhopper (*Empoasca fabae*)

Potato leafhopper (PLH) can be a serious economic pest of potatoes, even at low densities. PLH is unable to overwinter in the upper Midwest, but the insects are able to move northward in the spring with the aid of southerly winds. The first adults typically arrive in mid to late May and population levels can increase rapidly by June and July resulting in high density populations that coincide with large plants in the field. PLH tend to be attracted to large, mature plants, possibly because the sugar content of plant sap rises as the plant matures (13,14).

Adults are wedge-shaped, lime green and about 1/8 inch in length. Nymphs look similar to adults except they are smaller and wingless. When nymphs or adults feed on potatoes, the phloem becomes blocked which results in nutrient blockage within the plant. Feeding damage in potatoes often results in a characteristic v-shaped brown area at the end of leaves, commonly referred to as "hopperburn". In extreme cases, the entire leaf turns brown, however, the extent to which hopperburn appears does not correlate with the amount of damage caused by PLH. Some potato varieties are less susceptible to hopperburn than others, but plants may still suffer extensive phloem damage without exhibiting much hopperburn damage. Control efforts should be based on leafhopper counts rather than visual sampling for hopperburn damage (8,13,14,16).

Control options: Weekly inspections of potatoes are necessary to monitor adult and nymph population levels as even small infestations can cause serious damage to potatoes. Foliar sprays are generally recommended over soil-systemic insecticides because PLH is a mid-late season pest readily controlled by appropriate foliar sprays. Spraying should be considered in the overall control of other insects including Colorado potato beetle and green peach aphid, also, lessening or eliminating the advent of resistance. Spraying insecticides is recommended when the following thresholds are exceeded (14):

- <0.5 adults/sweep: do not treat unless nymphs exceed 2.5/25 leaves
- 0.5-1.0 adults/sweep: treat if adults persist at this level for 10-14 days or nymphs present
- 1.0-1.5 adults/sweep: treat within 5-7 days or immediately if nymphs are present
- >1.5 adults/sweep: treat as soon as possible

Aphids

Aphids are a concern, primarily because of the viruses they vector in seed potatoes. The diseases they transmit are only important when dealing with seed potato stock. Although aphids can injure foliage by feeding on plant sap, extremely high numbers are required before tuber yield is affected. There are two economically important aphid species found in Minnesota which affect potato, green peach aphid and potato aphid.

Green peach aphid (*Myzus persicae)*

Green peach aphid (GPA) is a serious pest of seed potato because it transmits potato leaf roll virus (PLRV) and potato virus Y (PVY or mosaic). The same viruses are also transmitted to potatoes if there are high infestation levels.

Aphids are soft bodied, pear-shaped insects that are creamy white to light peach and somewhat translucent. Green peach aphids are unable to overwinter in the upper Midwest but arrive by migrating from southern states in the spring. They reproduce very rapidly but tend not to feed in large colonies like other aphids.

Control options: Although heavy rains/irrigation can wash aphids off plant foliage, there are few cultural control options growers can use to manage the pests. Aphids have many natural enemies which should be conserved as much as possible. Insecticides should only be applied when the following thresholds are reached after examining a minimum of 25 single-leaf samples (14,15):

Aphid Thresholds

Fresh Market or Processing

- Early season: 50 wingless aphids (all species)
- After bloom: 100 wingless aphids (all species)

Fresh Market or Processing in Seed production Areas

- 7.5 green peach aphids
- 50 aphids (all species)

Seed Potatoes for PLRV Management

- 2.5 green peach aphids for PLRV susceptible varieties
- 7.5 green peach aphids for PLRV resistant varieties

- 25 potato aphids

Potato aphid (*Macrosiphum euphorbiae)*

Potato aphids range in color from pale green, yellow green, to pink. Potato aphids also develop large populations quickly but do not transmit PLRV or PVY as efficiently as green peach aphids. Like the green peach aphid, large numbers of potato aphids can affect the yield of processing potatoes. They overwinter in the upper Midwest as eggs on cultivated and wild roses, raspberries and shrubs and trees in the Rosaceae family (14,16). Treatment thresholds are noted in the discussion regarding green peach aphid.

Occasional pests of potatoes:

Aster leafhopper (*Macrosteles quadrilineatus*)

Aster leafhoppers (ALH) are similar to potato leafhoppers (PLH) but are olive green in color with two rows of black spots on the head. Unlike PLH, ALH do not reproduce on potatoes and as such, only adults will be found on potatoes. ALH overwinter in northern climates but also migrate from the south in the spring. They are pests because they can vector the aster yellows phytoplasma pathogen. Infected potatoes develop twisted, purplish leaves and small tubers. Also, if infected tubers are processed for chipping, they will turn dark in color. Newly sprouted potatoes are the most susceptible to infection while mature plants are almost completely resistant. Aster leafhoppers obtain the phytoplasma by feeding on infected weeds before moving into potatoes; they do not obtain the disease by feeding on infected potatoes (14,16).

Control options: Systemic insecticides applied to young plants are very effective. If systemic insecticides are used early in the season, foliar applications should not be necessary for the remainder of the season. If systemic insecticides are not used, foliar sprays should be considered once the following thresholds are exceeded:

- 1 ALH adult per sweep and infectivity is high (2%)
- 2 ALH adults per sweep and infectivity is low (2%)

University of Wisconsin extension entomologists typically monitor ALH and provide phytoplasma infectivity information. If this information is not available, growers usually assume an infectivity rate of 4-5% (14).

Potato flea beetle (*Epitrix cucumeris*)

Adult potato flea beetles are occasional pests that chew small, circular holes on the underside of leaves resulting in leaves having a shot-holed appearance. Feeding by large populations of potato flea beetles

can cause the formation of small tubers. Larvae feed on the roots and tubers, but this feeding is rarely damaging. Adults overwinter in the soil and begin feeding on small potatoes upon emerge in the spring. These beetles cause the most damage to small plants. Adults are small, dull-black colored beetles about 1/16 inch in length with large hind legs (13,14,19).

Control strategies: If >50 flea beetles adults are observed after taking 25 sweeps with a sweep net, insecticidal control should be considered to avoid economic damage. Foliar sprays used to control the potato flea beetle should be coordinated with sprays that control other potato pests. For example, sprays used to control Colorado potato beetle and aphids will usually also control potato flea beetles. In addition, soil-applied insecticides usually provide enough control throughout the growing season that foliar sprays for flea beetles are unnecessary (19).

European corn borer *(Ostrinia nubilalis*)

European corn borer (ECB) is an occasional pest of potatoes. If the preferred host crop, corn, is not available in late spring, they can be a serious problem in potatoes. They overwinter as larvae in cornstalks or other grasses and emerge in late May-early June as moths. Wings of the adults are buff colored with dark lines; females tend to be larger and lighter in color than males. Moths mate after emerging and the females lay egg masses on a variety of both cultivated and uncultivated hosts. If the eggs are on potato plants, larvae will feed on foliage through the first instar and then bore into the stem where they continue to develop. Stem boring disrupts water and nutrient flow and causes the stem to turn brown. High larval numbers can negatively impact tuber development (14,16).

Control options: Plant potatoes as far as possible from corn stubble if it was not plowed under the previous fall. Although varieties differ in their tolerances to ECB, consider applying insecticides when the following threshold is exceeded: 1 egg mass/25 leaves (14).

Black cutworm (*Agrotis ipsilon*) and Variegated cutworm (*Peridroma saucia*)

Cutworms are rarely pests in potatoes, however, the black cutworm damages plants by feeding on tubers while the variegated cutworm feeds on foliage. Both cutworm species typically hide in the soil during the day and emerge at night to feed. Black cutworm adults migrate from southern states each spring and are attracted to fields possessing actively growing vegetation, thus, early planted potato fields are at greater risk for infestation by black cutworm than later-planted fields. Variegated cutworm overwinters in the soil as partially mature larvae, or pupae, and then emerges in the spring (2,14).

Control methods: The treatment threshold for black cutworm is 2 plants/100 with larvae present. For variegated cutworm, the threshold is 4 larvae/row-foot (14).

Sporadic and rare pests of potatoes:

White Grubs (*Phyllophaga spp.)*

White grubs are the C-shaped, white larvae of June beetles. The larvae live in the soil for 2-3 years, feeding on roots. Depending on temperature and soil moisture, larvae migrate vertically between the soil layers. White grubs feed primarily on the roots of grasses but potatoes can have white grub problems if planted following a field that was planted in sod or used as pasture. White grubs gouge large circular/ irregular holes out of the tubers (13).

Control options: Avoid planting potatoes following a sod, pasture or grain crop (14).

Wireworm (Coleoptera: Elateridae)

Wireworms are hard-bodied larvae of click beetles. The larvae are thin, shiny, and yellow/brown in color. Larvae spend 2-6 years in the soil, overwintering by burrowing deep into the soil, and then emerge as adults (13,16). Wireworm feed primarily on the roots of corn, small grains, and other grasses while they bore into potato tubers creating tunnels which decrease marketability. These tunnels also serve as entry points for fungal and bacterial pathogens (13,16).

Control options: Avoid planting potatoes following sod, pasture or small grains. If planting potatoes after a grass crop, test the soil to determine population levels by taking soil samples or baiting with buried food (13,16).

Tarnished Plant Bug (*Lygus lineolaris*)

Tarnished plant bugs are rarely pests in potatoes. Nymphs and adults feed on a wide range of plants and may move into potatoes after an adjacent crop is harvested or after weeds dry out along field edges and large populations may appear on potatoes by mid-late July. The small, greenish-brown bugs overwinter as adults in plant debris within and around fields.

Tarnished plant bugs withdraw plant sap and inject a toxin while feeding with their piercing-sucking mouthparts which causes plant tissue to die. This feeding results in small, circular, brown areas on leaves. Feeding damage and yield reduction in potatoes caused by tarnished plant bug is not known. Young potato seedlings may be more susceptible to the feeding damage than established plants (11).

Control options: Decreasing weed populations in fields and along edges may prevent build-up of tarnished plant bugs that move into potatoes. Insecticides used to control other insects typically controls tarnished plant bugs as well. Treatment specifically for tarnished plant bugs should only be made when >25 adults are found in 25 sweeps (14).

Control options for potato insect pests (type of control/insecticide class) (19,21,22): *Biological*

> Abamectin (Agri-Mek 0.15EC). AgriMek is labeled to control Colorado potato beetles, leafminers and spider mites. The labeled rate is 8-16 oz/acre, not to exceed 32 oz/acre/

season. No more than 2 sequential applications of Agri-Mek should be made. There is a 12 hr. REI and a 14 day PHI. Potassium salts of fatty acids (M-Pede). M-Pede is labeled for use on aphids; control of green peach aphid requires the use of a companion insecticide. Product must contact aphids to be effective. The labeled rate is 1-2% by v/v (volume/volume). There is a 12 hr. REI and a 0 day PHI. *Bacillus thuringiensis* var. *tenebrionis* (Novodor). Novodor is most effective at controlling first and second instar Colorado potato beetle larvae and as such, applications should be timed accordingly. Novodor is applied at 1-4 qts/acre, there is a 4 hr. REI and a 0 day PHI. Spinosad (SpinTor 2SC). SpinTor is labeled to control Colorado potato beetles, European corn borer and leafminers. The labeled rate is 3-6 oz/acre, not to exceed 21 oz/acre/season. SpinTor should not be applied to consecutive generations of CPB or applied more than twice to a single generation. There is a 4 hr REI and a 7 day PHI.

Nicotynl Formulations

Thiamethoxam (Platinum and Actara). Platinum is labeled as a soil-applied systemic insecticide for control of Colorado potato beetles, aphids, potato leaf hoppers and flea beetles. The labeled rate is 5-8 oz/A of product or 0.078-0.125 lbs AI/A. Actara is the foliar version of Platinum, applied at 1.5 oz/A of product or 0.046 lb AI/A (max of 2 applications). It is labeled to control Colorado potato beetles and potato leafhoppers and should NOT be applied if an application of Platinum has been made. Imidacloprid (Admire 2F). Admire is labeled to control aphids, flea beetles, leafhoppers, wireworm larvae, and Colorado potato beetles. The labeled rate is 0.9-1.3 oz/1000 row-feet. The product can be in a band prior to planting, applied in-furrow at planting, or applied as a side-dressing or over-row at ground cracking when hilling. Do not exceed 0.31 lb. AI of Admire and/or Provado per acre in a single growing season. There is a 12 hr. REI and a 21 day PHI. Imidacloprid (Provado 1.6F). Provado is a foliar spray labeled to control flea beetles, leafhoppers, Colorado potato beetles, and aphids. The labeled rate is 3.75 oz/acre, not to exceed 0.2 lb. AI/acre/year. Also note: no more than 0.31 lb. AI/acre of Admire and/or Provado should be applied in a single growing season to a crop. For resistance management, do not use Provado if Admire was previously applied to the soil. A minimum of seven days should lapse between treatments. There is a 12 hr. REI and a 7 day PHI.

Carbamates

Carbaryl (Sevin XLR Plus). Sevin XLR Plus is labeled for control of leafhoppers, European corn borer and Colorado potato beetle. The labeled rate is 0.5-2 qt/acre and total applied product should not exceed 6 qts/acre. Sevin XLR Plus has a 12 hr. REI and a 7 day PHI. Oxamyl (Vydate L). *RUP. Vydate L is labeled for control flea beetle, Colorado potato beetle, and potato leafhopper. The labeled rate for Vydate L is 1-2 gal/acre when applied in-furrow and 1-4 pt/acre when foliar applied. When applied in-furrow and foliar, minimums of 20 and 4 gallons, respectively, must be used. Apply at 5-7 day intervals, not

to exceed 6 treatments/year and not to exceed 36 pts/acre. There is a 48 hr REI and a 7 day PHI for Vydate L. Carbofuran (Furadan 4F). *RUP. Furadan 4F is labeled for control of flea beetle, Colorado potato beetle, European corn borer and potato leafhopper. The labeled rate is 1-2 pts./acre and not to exceed 2 applications and 2 pts/season. There is a 48 hr. REI and a 14 day PHI. Methomyl (Lannate LV). *RUP. Lannate is labeled to control leafhoppers, aphids and flea beetles. The labeled rate is 0.5-3 pts/acre. Total applied product must not exceed 4.5 lbs. AI/acre and may not exceed 10 applications/ season. There is a 48 hr. REI and a 6 day PHI.

Pyrethroids

Esfenvalerate (Asana XL). *RUP. Asana XL is labeled to control flea beetle, potato leafhopper, Colorado potato beetle, European corn borer, and potato and buckthorn aphid. The labeled rate is 5.8-9.6 oz/acre, not to exceed 0.35 lb. AI/acre/season. Livestock should not eat the treated vines. There is a field REI of 12 hr. and a 7 day PHI. Cyfluthrin (Baythroid 2E) *RUP. Baythroid is labeled to control flea beetle, potato leafhopper, European corn borer and Colorado potato beetle and suppress aphid species. The labeled rate is 0.8-2.8 oz/acre not to exceed 6 applications or 16.8 oz/year. The field REI is 12 hr and there is a 0 day PHI. Permethrin (Ambush, Pounce 3.2EC) *RUPs. Ambush and Pounce are labeled to control flea beetles, potato and aster leafhopper, Colorado potato beetles, tarnished plant bugs, and cutworms. The labeled rate for Ambush and iPounce 3.2EC is 3.2-12.8 oz/acre and 4-8 oz/acre, respectively. Applied rates of Ambush and Pounce should exceed 1.6 lbs. AI/acre/season. There is a field REI of 12 hr. and a 14 day PHI for both products.

Organophosphates

Phorate (Thimet 20G) *RUP. Thimate can be used either at planting as a systemic insecticide or post-emergence. Thimate is labeled to control flea beetle, aphids, leafhopper, wireworm, flea beetle and early season Colorado potato beetle when applied at planting. When applied after emergence, it controls aphids, leafhopper, early season Colorado potato beetle and suppresses wireworm. At planting: product is applied at a rate of 8.5-11.3 oz./1000 linear row feet in light or sandy soils and 13-17.3 oz/1000 row feet in heavy or clay soils. Thimet should not be applied to muck soils. Post emergence: 8.5-11.3 oz/1000 linear row feet. No more than one application should be made in a year. There is a 48 hr. REI and a 90 day PHI. Disulfoton (Di-Syston 15G) *RUP. Di-Syston is labeled to control potato leafhopper, aphids, and flea beetles. This product also reduces early season populations of Colorado potato beetle. Di-Syston is a systemic soil insecticide that is applied in bands on each side of the row, beneath the soil surface or in the seed furrow at planting. It can also be broadcast and incorporated prior to planting. Di-Syston is applied at rates of 15-23 oz/1000 linear row-feet. There are 48 hr and 72 hr REIs for areas receiving >25"and <25" of rain annually, respectively. There is a 75 day PHI regardless of rainfall. Methamidophos (Monitor 4EC) *RUP. Monitor is labeled to control flea beetle,

Colorado potato beetle, potato leafhopper, European corn borer and aphids. Monitor is a foliar insecticide that is applied at rates of 1.5-2 pts/acre on a 7-10 day schedule. There is a field REI of 48 hrs. and a 14 day PHI. If the average rainfall is <25"/year, the REI increases to 72 hrs. Monitor has a 14 day PHI. Phosmet (Imidan 70WP). Imidan is labeled to control flea beetle, Colorado potato beetle, European corn borer and potato leafhopper. Imidan is a foliar insecticide applied at a rate of 1.3 lbs/acre. The product is applied on a 10 day schedule with the total applied product not to exceed 6.7 lbs. There is a field REI of 24 hrs. and a 7 day PHI. Imidan is only labeled for potatoes which are to be machine harvested. Azinphos-methyl (Guthion 2L, 50WP). *RUP. Guthion is labeled to control flea beetles, Colorado potato beetles, and leafhoppers. Guthion 2L and 50WP are foliar insecticides that are applied at a rate of 1.5 to 3 pt. and .075 lb. per acre, respectively. There should be no more than three applications per season and at least seven days should lapse between applications. There is a field REI of 48 hr. for mowing, irrigating, scouting and a REI of 4 days for all other activities. There is a 7 day PHI. Dimethoate (Dimethoate 2.67 EC). Dimethoate is labeled to control aphids and leafhoppers. Dimethoate is a foliar insecticide that is applied at a rate of 0.75-1.5 pts./acre. There is a field REI of 48 hr. and a 0 day PHI.

Organochlorines

Endosulfan (Thiodan 3EC, Phaser 3EC). *RUP. Thiodan is labeled to control aphid, flea beetle, potato leafhopper, Colorado potato beetle and European corn borer. The product is applied at rates of 0.7-1.3 qts./acre; not to exceed 6 applications/season and not to exceed 3 lbs. AI/acre/year. There is a field REI of 24 hrs. and a 1 day PHI.

Inorganic

Sodium aluminofluoride (Kryocide, Cryolite 96). Kryocide and Cryolite are labeled to control for use on Colorado potato beetle. The product is applied at rates of 10-12 lbs./ acre. A minimum of seven days should lapse between applications with <96 lbs. of product applied/season. There is a field REI of 12 hrs. and a 0 day PHI.

Pyridine Azomethine

Pymetrozine (Fulfill). Fulfill is labeled to control aphids. The product is applied at a rate of 2.75 oz/acre, not to exceed 5.5 oz./acre/season. Greatest control is achieved using >45 gallons water/acre. There is a field REI of 12 hrs. and a 14 day PHI.

Weeds

Weeds compete with potatoes for light, nutrients, and water. Weeds that exist in and around the field can also harbor disease pathogens and pest insects. Many annual weeds produce copious amounts of seeds that can remain viable in the soil for many years. Two cultivation practices used in potato production, drag-off and hilling, help to control small weeds. Drag-off involves the pulling of a spike-tooth or flex-tine through the top two inches of the soil after the potatoes have sprouted but before the sprouts are within the top 2 inches of the soil surface. Hilling involves placing soil onto the potatoes as they grow which prevents greening of tubers, facilitates tuber development and aids harvesting. Hilling continues until the plants reach heights of 14-16 inches. The soil covers weeds that were between the rows, but as weeds get larger, they often penetrate through the additional soil. Weeds can be divided into the following categories: annual broadleaf, annual grasses and perennial weeds (2,16,17,20).

Annual Broadleaf Weeds

Many broadleaf weeds adversely potato production in Minnesota. In absence of control, weeds can significantly reduce yields. Some examples of annual broadleaf weeds are: velvetleaf (*Abutilon theophrasti*), *redroot* pigweed (*Amaranthus retroflexus*), giant and common ragweed (*Ambrosia trifida* and *Ambrosia artemisiifolia, respectively*) and common lambsquarters (*Chenopodium album).* Since velvetleaf, redroot pigweed, ragweed and lambsquarters grow taller than potatoes; they may out-compete potatoes for available light and soil nutrients. Potatoes grown on irrigated land may be infested with buckwheat (*Polygonum convolvulus*), Eastern black nightshade (*Solanum ptycanthum*), hairy nightshade (*Solanum sarrachoides*), and bedstraw (G*alium aparine*). Since nightshade is from the same plant family as potatoes, it may also attract the same pests.

Annual Grasses

Annual grasses cause significant problems with potato production because of their fast growth and ability to compete for resources. Additionally, they are tolerant to extreme moisture and temperature variation once established. They can be very difficult to eliminate from production areas and given their reproductive potential, they require management/control prior to seed-set. Some common annual grass weeds are: foxtail (*Setaria spp.*), wild proso millet (*Panicum miliaceum*), and crabgrass (*Digitaria spp*).

Perennial Weeds

Perennial weeds adversely affect potato production because their strong roots or rhizomes sometimes grow directly into the tubers. Cultivation is not an effective control method because of the buds on the rhizomes. The best control is to eliminate weeds before potatoes are planted in the field. Some common perennial weeds found in potato fields include yellow nutsedge (*Cyperus esculentus*) and quackgrass (*Agropyron repens*).

Preemergence Herbicides (19,22)

- DCPA (Dacthal) is a preemergent herbicide applied at 3-8 lbs./acre on course-textured soils with <2% organic matter and 14 lbs./acre on fine-textured soils. It is not effective on muck or other soils high in organic matter. The product is applied immediately after planting or drag-off. Dacthal provides good control of the annual grass weeds, lambsquarters and purslane while it provides poor or no control of ragweed, velvetleaf, and nightshade. There is a 24 hr. REI.
- Metolachlor (Dual Magnum, Dual II Magnum) is a preemergent herbicide applied at 1-2 pts./ acre. Dual is applied after planting and incorporated uniformly before potatoes emerge. May also be applied at 1.67 pts./acre after hilling. Dual may delay maturity or reduce the yield of early maturing potato varieties if cold, wet soil conditions occur after treatment. Dual provides good control of the annual grass weeds, nightshade, and pigweed but provides poor to no control of lambsquarters, ragweed, smartweed and velvetleaf. There is a 24 hr. REI.
- Trifluralin (Treflan HFP, Trilin, Trifluralin) is a preemergent herbicide applied at 1-2 pts./acre. Trifluralin is applied after planting and incorporated uniformly. It is not effective on muck or other soils high in organic matter. Trifluralin gives good control of the annual grass weeds, lambsquarters, and pigweed but provides poor control of ragweed, smartweed, velvetleaf, and nightshade. There is a 40-60 day PHI and a 12 hr. REI.
- EPTC (Eptam7E or 10G) Eptam 7E and Eptam 10G are pre-emergence herbicides applied at a rates of 3.5-7 pts./acre and 30-40 lbs./acre, respectively. The products are applied after planting, after drag-off, or as a directed spray at lay-by. Eptam must to be incorporated immediately to be effective. These products provide good control of the annual grass weeds and pigweed, fair control of yellow nutsedge, lambsquarters, nightshade and velvetleaf and poor control of ragweed and smartweed. There is a 45 day PHI and a 12 hr. REI.
- Metribuzin (Lexone or Sencor 4F or 75DF) The 4F and 75DF formulations are applied at rates of 1 pt./acre and 0.67 lb./acre, respectively on course-textured soils (>2% organic matter); 2 pts./ acre, 4F; 1.3 lbs./acre, 75DF, on fine-textured soils and muck. Apply just before potatoes emerge and after drag-off. Lexone or Sencor provide fair control of the annual grass weeds and good control of most annual broadleaf weeds except nightshade. There is a 60 day PHI and a 12 hr. REI.
- Linuron (Lorox 50DF) is a pre-emergence herbicide applied at 1.5 lbs./acre (course textured soils, 1-2% organic matter) and 4 lb./acre (fine-textured and muck soils). Apply after planting but before the potatoes emerge and if practical, after drag-off. Do not apply Lorox on soils that have <1% organic matter. Apply Lorax when weeds are <2 inches tall. Lorax provides fair control of the annual grass weeds and good control of most annual broadleaf weeds except for nightshade. There is a 90 day PHI and a 24 hr. REI.
- Pendimethalin (Prowl 3.3E, Pendimax 3.3E) are preemergent herbicides applied at a rate of 1.2-3.6 pts./acre. May also be applied as an early post-emergent insecticide as long as the potatoes are not stressed. Not for use on muck soils. Prowl and Pendimax provide good control of the annual grass weeds and pigweed, however, both provide poor control of nightshade, ragweed, and velvetleaf. There is a 60 day PHI and a 24 hr. REI.
- Rimsulfuron (Matrix 25 DF) is a preemergent herbicides applied at a rates of 1-1.5 oz./acre at hilling, drag-off, or reservoir tillage. Matrix provides good control of annual grass weeds except crabgrass and pigweed and fair to poor control of many annual broadleaf weeds. There is a 60

day PHI and 4 hr. REI.

Postemergence Herbicides (19,22)

- Metribuzin (Lexone or Sencor; 4F or 75 DF) provides fair control of annual grasses and good control of the many annual broadleaf weeds. The 4F and 75DF formulations are applied at rates of 1.0 pt/acre and 0.67 lb./acre, respectively, not to exceed 1 lb. AI/acre/year. Do not apply to early-maturing or red skin varieties or within 1 day of using other pesticides. Avoid spraying when the potatoes are 12-15 inches high. Lexone or Sencor may damage sensitive crops the following year. There is 60 day PHI and a 12 hr. REI.
- Sethoxydim (Poast) provides good control of annual grasses. Poast is applied at a rate 1 to 1.5 lb./ acre plus 1 pt. nonionic surfactant. Apply Poast to actively growing grasses, not to exceed 5 pt. per acre during the growing season. There is a 30 day PHI and a 12 hr. REI.
- Rimsulfuron (Matrix) provides good control of annual grasses except crabgrass and fair to poor control of many broadleaf weeds. Matrix is applied at rates of 1-1.5 oz/acre. Matrix should be applied to actively growing weeds after the potatoes have emerged. There is a 60 day PHI and a 4 hr. REI.
- Paraquat (Gramoxone Extra 2.5E) *RUP, is a postemergence broadleaf and grass herbicide. It is applied at a rate of 1.5 pts./acre plus 1 qt. COC or 4-8 oz. nonionic surfactant. Applied to emerged weeds before or after planting but before crop emerges. There is a 0 day PHI and a 12-24 hr. REI
- Glyphosate (Roundup UltraMax, UltraDry Custom, Glyfos, Glyfos X-tra, Glyphomax, Glyphosate, Glyphosate Original) is a postemergence broadleaf and grass herbicide. Glyphosate is applied at 0.75-1.1 lbs. acid equivalent (ae)/acre to weeds before crop emergence. These rates are for annual weeds at application volumes of 10-40 gal/acre. Lower rates are applied to perennial weeds. See individual labels for REI and PHI information.

Diseases

Potatoes are susceptible to a number of different types of diseases. Cultural practices, applications of fungicides and insecticides and planting disease-resistant varieties can all play a key role in managing potato diseases (16). Several of the most common potato diseases are described below, classified and grouped by the form of their transmission and followed by descriptions of the most effective types of control.

Insect-born Viral Pathogens

Potato Leafroll Virus (PLRV)

Potato leafroll virus, referred to previously in the section on disease-transmission via aphids, can also be introduced into a field by planting infected seed tubers. Mere contact with leaves of infected plants or machinery used on infected fields cannot transmit this virus. Infection by potato colonizing aphids is the only method of introduction from an outside source. When this introduction first occurs, referred to as current-season infection, little damage is usually observed. It is not until the following season, when infected tubers are used for planting the next crop that a serious loss in yield is affected (16). As previously mentioned, the replication of the PLRV occurs in the phloem cells of the potato plant (11,16).

Potato Virus Y (PVY)

Many aphid species transmit potato virus Y. This virus is often referred to as mosaic, since it can cause a number of disease symptoms, including severe mosaic, leaf-drop streak and potato vein-banding mosaic. Unlike PLRV, current-season infections of PVY may be apparent, depending upon the viral strain, the age of the plants at infection and climatic variables including temperature (16).

Management of viral pathogens

In the management of pathogens such as potato leafroll virus and potato virus Y, the most important initial factor to prevent infection is management of infection vectors. Refer back to the section on aphids for details on types of pest control.

Seed usage practices can also greatly reduce the occurrence of viruses. Selecting resistant varieties can lessen the impact of pathogens. Even more importantly, the use of certified seed tubers is essential in preventing the spread of any potato disease. Restrict use of machinery to certified seed stock and verify that tubers from past crops and volunteer potato plants are cleared from field before planting (16).

Other potato pathogens, such as potato virus X (PVX) and potato virus S (PVS) are transmitted via mechanical contact (18). This requires implementing strict sanitation methods including the use of high-pressure steam on any equipment used when storing seed stock and harvesting potatoes. Some chemicals, including 3% trisodium phosphate, calcium hydroxide, quaternary ammonium compounds, chlorine dioxide and sodium hypochlorite, are efficacious in the destruction of viral pathogens including: (16).

Bacterial Pathogens

Blackleg and Soft Rot

While blackleg and soft rot have two different sources and forms of contamination, the bacteria that causes them, *Erwinia carotovora* subspecies *atrospetica* and *carotovora*, respectively, are closely

related and can both attack at any point during the season. *Erwinia carotovora atroseptica* can only be transmitted via contaminated seed and is usually found in potato crops grown in temperate climates. Infection by this bacterium results in an inky black to light brown decay at the base of the stem (16). Because of the method of transmission, using clean, certified seed is the most important step in preventing blackleg (18). *E. carotovora carotovora*, on the other hand, can enter wounds of the potato plant itself and is found in a variety of hosts worldwide. It also causes an inky black or brown decay found around the stem and petioles (16). Since both these bacteria reproduce under anaerobic conditions, they are commonly a problem when soil and tuber conditions become anoxic. Preventing carbon dioxide build-up is essential in maintaining a high concentration of oxygen in the soil (18).

Ring Rot

The bacterium *Clavibacter michiganensis* subspecies *sepedonicus* (aka *Corynebacterium sepedonicum)* causes ring rot in potato crops. Bacterial slime and infected seed tubers transmit this pathogen from one generation to the next (18). Once plants become infected with ring rot they will wilt and leaves will become stiff, pale and slightly rolled at the margins.

Ring rot is named for the characteristic breakdown of the vascular ring within the potato, which can be observed by cutting into the tuber crosswise. Advanced stages of ring rot will cause a milky substance to ooze from the base of the plant's stems when cut (16). When infected seed is cut, the bacterium can be transmitted to the cutting instrument and to the next 20-100 seed pieces that are cut in the production operation. While a low percentage of several potato diseases can be tolerated, the presence of any degree of ring rot eliminates crop viability (16). Using certified seed is the most effective way to avoid ring rot in a potato crop (18).

Common scab

Common scab, *Streptomyces scabies,* is caused by a soil-born bacteria. The disease doesn't affect eating quality, but lesions blemish tubers and reduce their commercial grade and marketability. Scabbed tubers tend to shrink excessively during storage and are often invaded by secondary soft-rotting organisms. The bacterium overwinters in the soil where it persists indefinitely in the absence of a suitable host. Fields that receive heavy applications of manure are particularly susceptible to the buildup of scab in the soil. Infection occurs through natural openings in the plant including lenticels and stomata. Soils with a pH between 5.5-7.5 that have been in continuous potato production for several years are likely candidates for losses to common scab. Symptoms of scab infection appear as brownish spots that are small at first but later enlarge. The resulting lesions may be large, raised and corky or more frequently, they appear as small, discolored areas that occur only on the tuber surface. Thin-skinned potato varieties are more severely affected than other varieties, but scab can affect any varieties. Scab shouldn't be confused with enlarged lenticels that are found on tubers grown in excessively wet soils. In severe cases of pit scab, small, circular lesions extend into the flesh several millimeters. Control is best achieved by maintaining a soil pH between 5.2-5.8. Scab-free seed pieces should be planted on land that is free from scab. Rotations of 3-5 years out of potatoes are recommended. Seed treatment with mancozeb formulations

helps to reduce scab severity.

Fungal Pathogens

Fungal pathogens are present throughout the growing season; at planting, during growth, at harvest and during storage. Many fungicides are available which provide some level of disease suppression or management of various fungal pathogens. These products are either those applied as via foliar spray, called protectant fungicides, or those applied to the soil, called systemic fungicides, which are taken up through the plant vascular system. These fungicides can be either broad or narrow in spectrum, pertaining to the type of fungal pathogen controlled.

Early Blight

Early blight, caused by the fungus *Alternaria solani*, overwinters as spores and mycelia inside potatoes and other related plants. The disease overwinters as inoculum and is disseminated in the spring. Anything planted in a field where early blight was present the previous year is very like to be infected. Small tubers are easily infected, often without visible signs of being wounded, but mature tubers will be infected only if wounded (16,18). Favorable conditions including warm weather aid development of early blight with the peak of growth usually occurring in July or August (16). The disease appears as small, circular brown spots on the potato plant's lower leaves. The lesions grow and may eventually join together forming larger patches. Early blight appears as sunken patches on the tubers, surrounded by brown or purple edges (16).

Late Blight

Phytophthora infestans is the pathogen that causes late blight. It is the same species that was responsible for the Irish Potato Famine in the 1840s and continues to be one of the most important threats to potato yield worldwide (16). Potato growing regions that experience cool, damp weather are ideal for development of the disease because lower temperatures combined with high humidity initiate spore release. While late blight often appears at the end of the growing season, it can occur earlier as well, since cool and damp conditions can be common in the spring and autumn. Late blight first appears on leaves as pale, water-soaked lesions. These lesions enlarge, join together and eventually become brown or purplish-black in color. The disease appears as a copper-brown dry rot on tubers (16).

Managing Early Blight and Late Blight

Rotating crops and implementing practices that reduce tuber injury at planting are the most effective ways to prevent the onset of early blight and late blight. The removal of overwintering inoculum, including field debris, volunteer potatoes and weed hosts from the field will reduce the amount of disease material in the field prior to planting. Selecting fungus-resistant varieties, preventing excessive stress from insects and diseases, and applying appropriate fertilizers also help to minimize the chances

of fungal infection. Additionally, selecting fields that are well drained reduces the likelihood of the crop developing early blight or late blight (16,18).

Fusarium Dry Rot

Fusarium sambucinum is the fungal pathogen that causes dry rot. It manifests on tubers as wrinkled and sunken skin with rotting patches ranging in color from brown to black (16,18). Dry rot overwinters as spores or mycelia within the soil (16). Proper harvesting procedures including, minimizing bruising or damaging tubers and waiting to harvest tubers until vines are completely dead, will help prevent the onset of dry rot (16).

Pink Rot

Pink rot, *Phytophthora erythroseptica,* is a late season disease of potatoes that results in wilting, chlorosis and the development of aerial tubers. Tubers become infected through diseased stolons and the disease progresses through the tuber with the line of demarcation between healthy and infected tissue appearing as a dark black line. Infected tissues are spongy but intact and are salmon pink when exposed to the air. The fungus that causes pink rot is soilborn and overwinters as oospores. Infection occurs in wet, poorly drained soils which remain wet for extended periods of time. High organic matter also contributes to the development of pink rot. Planting in well-drained soils and properly managing irrigation are key in preventing disease development. Fungicide treatments with mefenoxam provide some level of control (2).

Black scurf

Black scurf, *Rhizoctonia solani* Kühn, is responsible for black scurf and Rhizoctonia canker. The disease can be both seed and soil born with mycelia and sclerotia residing among organic debris in addition to infecting seed. Although the seed is most vulnerable early in the growing season, plants can be attacked at any time during the season.

Silver scurf

Silver scurf, *Helminthosporium solani,* is a common and widespread disease of potatoes that favors high soil moisture and high humidity. Symptoms are confined to the tubers and appear as light to dark brown, round or irregular spots that develop on the tuber surface. On wet tubers, the spots are silvery and glassy and easily observed. After prolonged storage under warm, moist conditions, spores form in the diseased spots and make them look sooty or smudgy. The affected skin sloughs off and tubers shrivel and shrink. The color of red-skinned potatoes may be completely destroyed by the disease. Silver scurf overwinters in infected tubers and other debris in storage and those left in the soil after harvest. Infection of healthy tubers occurs through wounds or lenticels. Cultural controls including the use of disease-free seed and rotating crops will reduce the incidence and severity of the silver surf. Some fungicides are labeled for control (2).

Table 1. Treatment options for disease pathogens in potato (19).

Disease	Treatment/control method	Comments
Blackleg	Plant cut seed tubers that have been stored under conditions for rapid healing of cut surfaces and treated with a labeled seed treatment.	Plant whole seed tubers where possible
Early blight	Bravo Ultrex: 0.7-1.4 lbs/A Bravo 500: 1-2.12 pts/A Bravo Weather Stik: 0.75-1.5 pts/A Terranil Cu: 1.7-3.4 pts/A Echo 75WDG: 1.2-1.5 lbs/A Dithane, Manzate, Penncozeb, Manex II, Gavel 75DF: rate vary	Begin applications at low rates when vines are exposed to disease. Repeat apps at higher rates at 7-day intervals. Avoid droughty, wet or compacted soils and other conditions that might add stress to the crop. See labels for REI and PHI.
Late blight	Destroy all cull piles; Bravo and Echo: 2-3 pts/A (flowable); 1.5-2.5 lbs/A (dry).	48 hour REI, 7 day PHI

Fusarium dry rot	Mertect 340-F: 2.5 pts/100 gallons water. Treat potatoes as they go into storage.	Should be applied uniformly as a fine mist. Avoid bruising at harvest. Cure potatoes in storage at 60F before lowering temperature, ventilate.
Rhizoctonia canker	Avoid heavily infested fields and plant uncontaminated seed tubers	
Scab	Plant resistance varieties; follow 3-4 year rotation schedule.	Maintain high moisture levels during tuber set and enlargement. Do not apply manure or other organic matter prior to planting. Also avoid excessive liming and maintain acid soil pH.
Verticillium wilt	Employ at least a 2 year rotation with small grains to manage fungal populations in the soil.	Good weed control is important in reducing pathogen populations.
Viral diseases	Plant only certified seed tubers; control aphids and leafhoppers with insecticides.	Practice clean cultivation; rogue first infected plants, including tubers.

Root knot nematode	Methyl bromide or sodium methyl dithiocarbamate or Vydate L	Sample fields during the growing season for nematodes; avoid planting in fields with high numbers of root-knot and/or lesion nematodes.

Acknowledgements

The Minnesota potato crop profile was compiled by Kathleen Bennett and Patrick O'Rourke and edited by W. D. Hutchison, Minnesota Project, North Central Pest Management Center and Department of Entomology, University of Minnesota.

Contacts

Mr. Patrick O'Rourke
MN Project, North Central Pest Management Center
Dept. of Entomology
219 Hodson Hall
1980 Folwell Avenue
St. Paul, MN 55108
Email: orour010@tc.umn.edu

Insects:

Dr. Ted Radcliffe
University of Minnesota
Department of Entomology
219 Hodson Hall
1980 Folwell Avenue
St Paul, MN 55108
Phone: 612-624-9773

Dr. Dave Ragsdale
University of Minnesota
Department of Entomology
219 Hodson Hall
1980 Folwell Avenue
St Paul, MN 55108
Phone: 612-624-6771

Dr. William D. Hutchison
University of Minnesota
Pesticide Survey & Impact Group
Department of Entomology
219 Hodson Hall
1980 Folwell Avenue
St Paul, MN 55108
Phone: 612-624-1767

Plant Diseases:

Dr. Roger Jones
University of Minnesota
Plant Pathology
212 Stakman Hall
1519 Gortner Ave
St Paul, MN 55108
Phone: 612-625-6290

Weeds:

Dr. Roger Becker
University of Minnesota
Department of Agronomy/Plant Genetics
Agronomy and Plant Genetics
A 203A Hayes Hall

1509 Gortner Ave
St Paul, MN 55108
Phone: 612-625-5753

References

1. Minnesota Agricultural Statistics Service. 2000. Minnesota agricultural statistics, 2000. St. Paul, MN.

2. Delahaut, K.A., L. Binning, W. Stevenson, and J. Wyman. 2000. Crop profile for potato in Wisconsin. http://pestdata.ncsu.edu/cropprofiles/docs/wipotatoes.html

3. USDA. 1999. Potatoes and Sweet Potatoes, Final Estimates, 1992-1997. http://usda.mannlib.cornell.edu/usda/reports/general/sb/b9620899.pdf

4. NASS (National Agricultural Statistics Service) http://www.usda.gov/nass/pubs/agr00/acro00.htm

5. Potatoes, Minnesota Department of Agriculture. 2001. www.mda.state.mn.us/maitc/Potatoes.PDF

6. Welty, Celeste and Casey Hoy. Colorado potato beetle in the home garden. HYG-2204-93. www.ag.ohio-state.edu/~ohioline/hyg-fact/2000/2204.html

7. Antonelli, Arthur L. Colorado Potato Beetle. Washington State University. Extension Bulletin 0919.

8. Crop profile for potato in Ohio. 2000. http://pestdata.ncsu.edu/CropProfiles/docs/OHpotato.html

9. Grafius, Edward. 1984. Potato Insect Pests. MSU Ag Facts. Michigan State University. E-965.

10. Ghidiu, Gerald. Colorado Potato Beetle. Rutgers Cooperative Extension. FS224.

11. Bishop, G.W., H.W. Homan, L.E. Sandvol, R.L. Stoltz. 1982. Management of Potato Insects in the Western States. WREP-64.

12. Bessin, Ric. 1999. Colorado Potato Beetle Management. www.uky.edu/Agriculture/Entomology/entfacts/veg/ef312.htm

13. Metcalf, R.L. 1962. Destructive and Useful Insects: their habits and control. McGraw Hill Book

Co., NY.

14. Foster, R. and Flood, B. 1995. Vegetable Insect Management with Emphasis on the Midwest. Meister Publishing Company. Willoughby, Ohio.

15. Robinson, Robert. 1976. Controlling Green Peach Aphids on Potatoes. Oregon State University. #860.

16. Rowe, Randall C. 1993. Potato Health Management. American Phytopathological Society, St. Paul, MN.

17. Western Regional IPM Project. 1986. Integrated Pest Management for Potatoes in the Western United States. Western Regional Research Publication 011.

18. Crop profile for potato in North Dakota. 2000. http://pestdata.ncsu.edu/cropprofiles/docs/Ndpotatoes.html

19. Foster, R. 2002. Midwest vegetable production guide for commercial growers 2002. University of Minnesota Extension Service, BU-07094-S. St. Paul, MN.

20. Chase, R.W. 1981. Potatoes. MSU Ag Facts. Michigan State University. E-1526

21. Ragsdale, D. and E. Radcliffe. 2002. VegEdge: Colorado potato beetle http://www.vegedge.umn.edu/vegpest/cpb.htm

22. CDMS, Crop Data Management Systems. http://www.cdms.net/manuf/manuf.asp.

23. Stevenson, W.R., R. Loria, G.D. Franc and D.P. Weingartner. 2001. Potato disease compendium, second ed. American Phytopathological Society, St. Paul, MN.