Crop Profile for Potatoes in Maryland

(Adapted from Maryland Extension Bulletin 236 *Commercial Vegetable Production Recommendations*. Additional references are cited throughout this document.)

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General Production Information

- Maryland is the 32nd largest producer of potatoes in the U.S. (about 0.2% of U.S. production in 1997) (1).
- Potatoes are an emerging commodity in Maryland. Production more than tripled between 1995 and 1998, increasing from about 1,500 acres to 4,600 acres (2). Production in Maryland continues to grow while production in surrounding states has been declining (3).
- Maryland growers harvested 4,600 acres of potatoes in 1998 (2). About 50% of the potatoes harvested were destined for the fresh market. The rest was for processing (potato chips and other potato-based products) (3).
- The average annual production cost for potatoes in Maryland is about $1,326.00 per acre (4). In 1998 total production cost was about $6,099,600.00 (2).
- The cash value of potatoes harvested in Maryland in 1997 was about $6,521,000.00 or about $1,918.00 per acre (2).
- 80% of the fresh market and processing potato acreage in Maryland are monitored by professional crop consultants and managed with IPM practices.

Production Regions

Most of Maryland's potato production is concentrated in counties on the Eastern Shore. Nearly all the potatoes grown for processing (chipping) are grown in Dorchester county by a single company. Other Eastern Shore counties with considerable fresh market potato production include Cecil, Kent, Worcester and Somerset counties. A small amount of potatoes are grown for processing (chipping) in Western Maryland in Garrett county and on the Eastern Shore in Queen Anne's and Caroline counties (3, 36).

Production Methods

Potato production requires well-drained soils with a pH of 5.0 to 6.2; preferably between 5.6 to 5.8 (27). Wet soils promote disease and inhibit harvesting of tubers, and the development of scab is favored at pH levels above 5.2. Loose soils are best, since they are easily tilled and increase the ease of harvesting. Cover crops such as winter rye or wheat are often used to reduce weeds and erosion and to provide nutrients to the soil. Seedbeds are prepared by plowing and harrowing the field (5). Soil insecticides are used at planting to control wireworms and white grubs in fresh market potatoes in Delaware and Maryland (14). Potatoes are normally rotated with other crops, such as corn and vegetables, to preserve physical soil properties and lower the incidence of soil-borne diseases such as *Fusarium* wilt and *Verticillium*. Virtually all acres of potatoes are rotated out of production for one or two years (3). Fertilization is important, as potato vines and tubers extract a large amount of nutrients from the soil. Most fertilization is applied as side-dress treatments during the drag-off and hilling operations, as well as foliar feeds applied, if necessary, later in the growing season (3). Soil pH and nutrient levels are tested prior to planting and lime and fertilizer are added as needed (5). Practices for fresh market and chipping potatoes do not vary enough to make a distinction (3).

Growers use certified seed, usually B size to avoid cutting seed pieces, dusted with a fungicide just prior to planting (31). All seed potatoes are treated with fungicides to reduce the incidence of soil-borne pathogens (5, 6, 3). Potatoes are planted in Maryland between March 1 and April 5. Seeds are spaced 7 to 12 inches apart (depending on variety and how the harvested potatoes will be marketed) in 34 to 36 inch rows (6). Most Maryland growers irrigate using center pivot systems (3). For certain fresh market varieties, a vine-killing agent may be applied 10 to 14 days prior to harvest to facilitate harvesting and initiate maturing of tubers (5, 6, 3). However, this practice is not common in Maryland. Timing of vine killing varies, depending on the cultivar and how long tubers take to mature (14). This practice also reduces the spread of late blight from the foliage to the tubers (5). However, all processing and most fresh market acreage are harvested when vines are green or are allowed to senesce naturally before harvest (3, 31). Tubers are harvested after they have matured sufficiently, and when tuber temperature is at least 45 to 50ºF, to minimize bruising during the operation (7). For fresh market varieties, sprout inhibitors are applied 3 or more weeks after harvest directly to tubers that are to be stored (6, 3). (See "Storage" section for chemicals and rates used).

Insect Pests

Major Insect Pests in Maryland

Colorado Potato Beetle

Damage and Life Cycle: The Colorado potato beetle, *Leptinotarsa decemlineata*, is the most important insect pest in potatoes in the Northeast. Uncontrolled populations can completely devastate a potato field by early July (5). Adults overwinter in the soil and emerge from late April through May, when they invade host crops. Adults mate after they are established on the plants (8). This first generation of adults feeds on the foliage of emerging plants and can do considerable damage when populations are high, although young plants usually can outgrow the damage (5, 8). Females deposit eggs in clusters on the underside of leaves. A single female can produce about 500 eggs in a 3 week period before she dies. The larvae hatch in 4 to 8 days and feed on foliage for about 3 weeks, often stripping plants of leaves and leaving only the main branches. Because eggs are laid in clusters, larvae are distributed in clumps throughout the field (8). Larvae grow through several stages, all of which feed on the foliage (5). When mature, they construct a small spherical cell in the soil at the base of the plants, where they pupate. The second generation of adults emerges in 5 to 10 days, and beetles mate to produce a second generation of larvae. Adult beetles and larvae continue feeding on potato plants, but damage in midsummer is less severe because plants are larger and because beetle egg production is inhibited at temperatures above 80ºF. In Maryland beetles go through 2 generations and a partial third each growing season (8). In general, defoliation that occurs during the last 2 weeks before senescence will not affect crop yields (5).

Frequency of Occurrence: The Colorado potato beetle is the most economically important insect pest of potatoes in the mid-Atlantic and throughout the Northeast (5). It is an important management issue every year in Maryland (8). Yield loss varies depending upon the timing and level of infestation. Early season loss of control can result in up to 50% yield loss in some cases (14). Currently, yield loss is minimal if any at all (3). The proximity of a field to overwinter sites is an important factor affecting the severity of early season infestations (8).

Management: A variety of strategies are used in combination by Maryland growers to manage CPB populations. Crop rotation is critically important, and the growers plant potatoes as far as possible from fields previously planted in potatoes or other solanaceous crops (6). Many growers use a 2 to 3 year rotation into corn and grain crops (3). Scouting and treatment thresholds, as well as careful insecticide selection are important (6). For the processing acreage produced by one company in Dorchester County (2/3 of the state's acreage), a preseason evaluation is conducted each year to assess the infestation risk at each field site. Each field site is assigned a low, moderate, or high risk for CPB infestation based on 1) distance to the previous year's potato fields; 2) estimated overwintered population size around the nearest previous year's fields; 3) obstructions that impede the movement of beetles in the spring; and 4) spatial arrangement of other potato fields that may act as a trap crop. Early maturing varieties are planted at specific times and field locations to avoid high infestation risk. At-planting treatments of imidacloprid (Admire) are used according to the risk category as follows:

- 1) Low risk fields - either no preventive control or perimeter treatments of imidacloprid deployed as a toxic barrier to create an untreated refuge in the interior;
- 2) Moderate risk fields - perimeter treatments with imidacloprid with specific use of wider barriers along borders where major CPB invasions were expected;
- 3) High risk fields - rotations of whole-field treatments of imidacloprid and plantings of NewLeaf potatoes deployed with a minimum 20% refuge of non-expressing potatoes in the same or nearby field. A perimeter treatment of imidacloprid around the entire field consisting of at least 24 consecutive treated rows running parallel to and at least 30 m of the treated row length running perpendicular to the edges provides a sufficient barrier to prevent overwintered adult and first generation larval damage from reaching economic levels. This is done by turning on the insecticide delivery nozzles for the desired distance, while starting or finishing each planter pass. In many rotated situations, this strategy has resulted in control cost savings of up to 80% in large fields. In recent years, perimeter treatments are applied to more than 70% of the processing acreage (3).

Fields are scouted twice weekly following plant emergence, and the number of colonizing adults is noted. Often adult numbers are not numerous enough to justify insecticide treatment and growers delay spraying until after the first generation of eggs have hatched (8). Throughout the season thereafter, fields are scouted weekly for CPB to determine the need to spray. This new method of using sweep samples works very well and is more conservative (27). At least 10 sites per field are inspected along a V- or W-shaped path. At each site, one stem is examined from each of five adjacent plants, and the number of CPB adults, large larvae and small larvae are counted. As a general guideline, if more than 50 adults or 75 large larvae or 200 small larvae are counted per 50 stems, an insecticide treatment is applied (6). The amount of yield loss as a result of CPB feeding depends on the age of the potato plant. Superior varieties (short season) cannot compensate for early season defoliation by overwintered beetles, but during the last 30 days of the season, Superior can withstand up to 50% defoliation without yield loss (32). Because larvae have a clumped distribution, spot treatments may often be effective for controlling this pest (8).

Chemical Controls: As described above, at-planting application of imidacloprid (Admire 0.9-1.3 fl oz 2F/1,000 row ft) is used as a preventive measure (6), either as a whole-field or perimeter treatment. In most years, a preventive treatment of imidacloprid is used on about 60-70% of the acreage (3, 27). According to the label, imidacloprid is applied as a banded application during seedbed preparation, or in the furrow at planting, or is sidedressed on either side of the potato row at planting. However, virtually all acreage receiving imidacloprid are treated at-planting in the furrow (3).

Growers do not rely exclusively on Admire or Provado for CPB control. They use all available, effective pest management strategies such as crop rotation, pest scouting, treatment thresholds, and alternative insecticides. For rotated fields adjacent to beetle overwintering sites or contiguous to the previous year's potato fields, most of the colonizing adults can be killed by treating only a strip of rows along the field edge where the invasion is expected. Fields should still be monitored for beetles and other insect pests throughout the season (35).

Preplant or Planting Application:

- imidacloprid (Admire 0.9-1.3 fl oz 2F/1,000 row ft) (35).
- thiamethoxam (Platinum 5-8 oz 2SG/A) (35).

Foliar treatments are applied on an as-needed basis, based on scouting and established thresholds. Choice of insecticide is influenced by local adaptation of Colorado potato beetle populations, which have developed varying levels of resistance to a number of products. The following foliar products are used in Maryland (6):

- abamectin (Agri-Mek 8-16 fl oz 0.15EC/A) Less than approximately 2% of acreage is treated (14, 3).
- imidacloprid (Provado 3.75 fl oz 1.6F/A) Provado is not used in fields treated with Admire at planting. Approximately 15% of acreage is treated (3).
- endosulfan (Thiodan l.33-2.67 pt 3EC/A) Less than approximately 3% of acreage is treated (3).
- spinosad (Spintor 3-6 oz 2SC/A) Approximately 15% of the acreage is treated for both Colorado Potato Beetle and European corn borer (3).

Insecticide Resistance Management: The Colorado potato beetle has proven to be quite adaptive, and in some areas of the U.S., including Maryland, beetle populations have developed resistance to all major classes of insecticides (9, 14). Insecticide management to slow the development of resistance is critical to ensuring the continued effectiveness of the available chemical insecticides (9). Growers use all available management strategies for this pest, including crop rotation, scouting, following established treatment thresholds, alternating insecticides with different modes of action, and use of preventive perimeter treatments (6). For resistance management, perimeter treated fields create effective refuges that lower selection intensity while minimizing yield loss (3). When insecticides are used, proper timing, rates, and good spray coverage are important. The same insecticide is not used for subsequent generations of beetles in the same field. Piperonyl butoxide is a chemical that can be used in combination with organophosphates or pyrethroids to slow resistance. It works by blocking one of the beetle's resistance mechanisms and thereby increases insecticide effectiveness (9). Because of its expense, this synergist is not used by Maryland growers. Further, it is important to be mindful of CPB resistance when managing other insect pests in potato (6).

Alternative Controls:

- **Genetically Engineered Varieties:** Genetically engineered varieties of potatoes which express the toxic *Bacillus thuringiensis tenebrionis* protein are available and provide season-long control of CPBs (6). These varieties produce competitive yields in most years and are very resistant to CPB damage (3). In 1998 and 1999, about 5% of the processing acreage was planted in transgenic Bt varieties, while only a small number of acres for fresh market was planted for demonstrationalpurposes. In all fields planted in transgenic varieties, a portion of each field representing more than 20% of the acreage was planted in nontransgenic varieties to serve as a refuge to conserve susceptibility to the Bt protein in CPB populations. In 2000, very little if any acreage were planted in transgenic varieties due to the concerns about processed products with GMO ingredients (3).

- **Cultural Practices:** Crop rotation is a critically important means of reducing or delaying CPB infestations (9). Potatoes are not planted in fields where solanaceous crops were planted the previous year, so that overwintering adults have a longer dispersal route to find potato hosts (8). The resulting reduction or delay in colonization affects the rate of resistance development in the beetle population and can greatly influence the overall success of a CPB management program (9).
  Trap crops of early-planted potatoes around field edges in the spring are used by some growers to concentrate dispersing adults which are then removed by flaming or by vacuum suction. Similar techniques may be used to eliminate beetles in the fall from late-planted potato trap crops or from unkilled strips of foliage, thus reducing the number of overwintering adults (9). Removal of volunteer potato plants helps to reduce early beetle populations. Tillage is also used to reduce the emergence of overwintering adults in the spring (10).
- **Natural Enemies:** Colorado potato beetles have several natural enemies, but these do not normally provide sufficient control of the pest (9).

Frequency of Occurrence: Potato leafhopper is a serious annual pest of potatoes in Maryland, second only to Colorado potato beetle (14). Relatively low numbers of leafhoppers can cause a significant yield reduction (9). If uncontrolled, leafhoppers can cause 30 to 50% yield loss in some varieties, while other varieties exhibit symptoms of feeding injury but no significant yield loss (14, 3). Because nymphs are susceptible to desiccation, populations tend to be lower during very dry summers (11).

Management: Fields are monitored from early June through early August for the buildup of potato leafhoppers (6). Sweep net samples are used to monitor adult populations and leaves are inspected for the presence of nymphs (11). Growers make a foliar insecticide application when adult counts exceed 1 per sweep or if more than 1 nymph per 10 leaves is found (6). For adult-nymphal population combinations, treatment is suggested for the following:

- 1) if leafhopper counts are less than 0.5 adults per sweep, treatment is recommended only if there are 0.1 or more nymphs per leaf;
- 2) if leafhopper counts are 0.5 to 1.0 adults per sweep, treatment is suggested if nymphs are present or if adults have been present for more than two weeks;
- 3) if leafhopper counts are 1.0 to 1.5 adults per sweep, immediate treatment is recommended if nymphs are present or treatment is suggested within one week if nymphs are not present; and
- 4) if adults counts exceed 1.5 per sweep, immediate treatment is recommended regardless of nymphs present or absent (3). Chemical insecticides applied on an as needed basis are the primary means of controlling potato leafhoppers. Applications of imidacloprid at planting are also effective, but generally do not provide season-long control of leafhoppers (14, 3).

Chemical Controls: The following insecticides are used to control leafhoppers on potatoes in Maryland (6, 35):

- thiamethoxam (Actara 1.5 oz 25WDG/A) (control may require 2 applications at 7-to 10-day intervals)
- cyfluthrin (Baythroid 0.8-2.8 fl oz 2EC/A)
- disulfoton (Di-Syston 13.5-20.5 lb 15G/A). Disulfoton is broadcasted and incorporated before planting or is applied in the seed furrow or in a band on each side of the seed furrow.

An additional application may be sidedressed after plants become established or one of the following products may be used:

- azinphos-methyl (Guthion 2-3 pt 2L/A)
- phosmet (Imidan 2 lb 50 WP/A)
- methomyl (Lannate 1.5-3 pt LV/A)
- thiamethoxam (Platinum 5-8 oz 2SG/A)
- permethrin (Pounce 4-8 fl oz 3.2 EC/A)
- endosulfan (Thiodan 1.33-2.67 pt 3EC/A)
- oxamyl (Vydate L 1-4 pt 2L/A)

Preventive Applications:imidacloprid (Admire 0.9-1.3 fl oz 2FS/1,000 row ft) According to the label, Admire is applied as a banded application during seedbed preparation or in the furrow at planting or sidedressed on either side of the potato row at planting. This treatment is used on about 40% of the acreage to control both the Colorado potato beetle and the potato leaf hopper (3).

Rescue Treatments:

- imidacloprid (Provado 3.75 fl oz 1.6F/A) Provado is not used in fields treated with Admire at planting. Approximately 5% of the acreage is treated (3).
- permethrin (Ambush 3.2-12.8 fl oz 2EC/A or 4-8 fl oz Pounce 3.2EC/A) Approximately 30% of the acreage is treated (3).
- esfenvalerate (Asana XL 5.8-9.6 fl oz 0.66EC/A) Less than approximately 5% of the acreage is treated (3).
- dimethoate (0.5-1 pt 4EC/A) Approximately 10% of the acreage is treated (3).

Alternative Controls: No effective alternative controls are available for the management of this pest (14).

Wireworms

Damage and Life Cycle: Wireworms, the larvae of click beetles (Elateridae), feed on a variety of crop and non-crop plants. Several species of wireworms attack potatoes and can damage seed pieces, roots, and tubers. Most species spend 2 to 4 years in the larval stage, so adults and immatures may be present during the growing season (10). Adults emerge in May or June. Eggs are deposited in the soil in late spring (5). Larvae infest the soil, hollowing out seed pieces, pruning roots, and feeding on developing shoots. This damage makes plants more susceptible to fungal infection and other diseases. Root damage weakens plants and can lead to reduced stands, although this is generally not a common problem in Maryland (3). Damaged tubers have round entry holes. After 2 to 4 years of development and feeding, mature larvae pupate in the soil before emerging as adults to continue the cycle. Larvae and pupae overwinter deep in the soil (10).

Frequency of Occurrence

Wireworms are considered a minor pest problem in potatoes in Maryland (3). Yield loss ranges from 2-4%, average and maximum yield loss, respectively (3). Populations are often greater in fields continuously planted in small grains, or where rotations with field corn are used with no soil insecticide at planting. Fields with high crop residue or other organic matter also are favored by wireworms (14).

Management: Soils are sampled for wireworms prior to planting in fields that have a history of infestation, or fields previously planted in cereal or sod (10). If 5 or more wireworms are found in 20 soil samples, a soil insecticide is applied (6). Growers generally do not sample for wireworms in Maryland (3).

Chemical Controls: Soil insecticides are the only chemical means for controlling wireworms. They are usually applied at planting in Maryland (14).
The following products are used in Maryland (35):

- **Preplant Application:**
  - diazinon (21-28 lb 14G/A) This chemical is broadcasted and incorporated into soil just before planting.
  - disulfoton (Di-Syston 13.5-20.5 lb 15G/A) This chemical is broadcasted and worked into soil 2 to 3 inches.
- **Planting Application:**
  - disulfoton (Di-Syston 13.5-20.5 lb 15G/A) This chemical is broadcasted and worked into soil 2 to 3 inches.
  - ethoprop (Mocap 30 lb l0G/A, in the row) Less than approximately 5% of the acreage is treated (3).
  - phorate (Thimet 15 oz 15G/1,000 ft of row)Approximately 70% of the acreage is treated.

Alternative Controls: Crop rotation or frequent cultivation of the soil may help to reduce wireworm grub populations in the soil. Growers avoid planting in fields high in organic matter (5). No alternative control strategies are currently in use. Current research efforts include examining the effect of rye cover crops on wireworm survival (14).

Aphids

Green Peach Aphid, Potato Aphid, and Melon Aphid

Damage and Life Cycle: Several species of aphids feed on potatoes, and all inflict similar types of injury to plants. Aphids overwinter as eggs on a variety of host plants. Green peach aphids overwinter in the south and migrate into our area, or overwinter in greenhouses and are introduced with bedding plants. Potato aphids overwinter as eggs on wild and cultivated rose plants, and certain weed species including lambsquarters, yellow mustard, and redroot pigweed (5). Melon aphids overwinter in weeds and cold-tolerant crops (14). Aphid nymphs hatch in spring and feed until they mature. Adults of this first generation reproduce sexually, bearing live young which mature into winged adults and migrate onto crops. This generation feeds on plants and rapidly reproduces asexually, with a generation time of 5 to 7 days. Many overlapping generations occur, and populations can increase rapidly. Most species of aphids produce a winged, sexually reproductive generation near the end of the growing season (9). All three of these aphid species are important pests in other potato-producing states but have not been consistently damaging to potatoes in Maryland (9, 3). All three species attack plants throughout the growing season, but damage is usually worst in May and June, and again in the fall. Aphid infestations commonly begin in small scattered areas over the field. Aphids are found primarily on the underside of the leaves, where they suck sap from the plant. Green peach aphids favor mature lower leaves, while potato aphids are found primarily on terminal leaves and young stems (8). Infested leaves curl downward and may turn brown and die (9). When infestations are heavy, aphid damage can reduce plant vigor, size and yield, and may kill the plants (8). Aphids can cause a yield loss of approximately 30% (29). There is no evidence that aphids transmit viruses to potatoes in the Mid-Atlantic Region (14).

Frequency of Occurrence: The green peach aphid is a major pest of potatoes everywhere they are grown (10). The green peach aphid and the potato aphid are the most common species of aphids found on potatoes grown for the fresh market in the Northeast (5). The melon aphid is also found on potatoes in our area (6). Aphids are present every year, but typically affect potato yields only when their populations reach very high levels. In general, aphids do not cause any significant yield loss (3). Aphid outbreaks may occur following the application of certain insecticides, such as pyrethroids which suppress populations of their natural enemies (9).

Management: Fields are scouted for the presence of aphids 2 or 3 times during the growing season, in May and early June for the potato aphid, and in late June for the green peach aphid (8). About 70% of the acreage is scouted for aphids (14). Scouting is done by looking for wilting and curled leaves throughout the field. When aphids are detected, more intense sampling is done to determine infestation levels and natural enemy activity. An insecticide is applied to control potato aphids and green peach aphids if combined counts exceed 2 per leaf prior to bloom, 4 per leaf during blooming, or 10 per leaf within 2 weeks of vine killing. For melon aphids, the thresholds are lower: 1 per leaf prior to bloom, 2 per leaf during blooming, or 5 per leaf within 2 weeks of vine killing (6). Vine killing is not common in Maryland; however, for the chipping potatoes, vines are frequently killed for table stock (27).

Chemical Controls: The following insecticides are used to control potato aphid and green peach aphid on potatoes in Maryland (6):

- imidacloprid (Admire 0.9-1.3 fl oz 2FS/1,000 row ft) According to the label, Admire is applied as a banded application during seedbed preparation or in the furrow at planting or sidedressed on either side of the potato row at planting (Label). Imidacloprid is not applied specifically for aphids in Maryland (3).
- imidacloprid (Provado 3.75 fl oz 1.6F/A) Provado is not used in fields treated with Admire at planting. Imidacloprid is not applied specifically for aphids in Maryland (3).
- methomyl (Lannate-1.5-3 pt LV/A) is the most effective product against melon aphid. Lannate is not specifically used for aphids (3).
- methamidophos (Monitor 1.5-2 pt LV/A) Potato aphid and green peach aphid only. Monitor is not specifically used for aphids (3).
- endosulfan (Thiodan l.33-2.67 pt 3EC/A) Potato aphid and green peach aphid only. Thiodan is not specifically used for aphids (3).
- oxamyl (Vydate L 1-4 pt 2L/A) Potato aphid and green peach aphid only.Vydate is not specifically used for aphids (3)
- dimethoate (0.5-1 pt 4EC/A) Dimethoate is not specifically used for aphids (3).
- pymetrozine (Fulfill 2.75 oz 50WDG/A) (35)

The following insecticides are used to control melon aphid on potatoes in Maryland (6):

- imidacloprid (Admire 0.9-1.3 fl oz 2FS/1,000 row ft)
- pymetrozine (Fulfill 2.75 oz 50WDG/A) (35).
- methomyl (Lannate-1.5-3 pt LV/A) is the most effective product against melon aphid.
- thiamethoxam (Platinum 5-8 oz 2SG/A) (35).
- imidacloprid (Provado 3.75 fl oz 1.6F/A) (35).

Regardless of the foliar insecticide used to control aphids, thorough spray coverage on the underside of leaves is important (6). For localized infestations, spot treatments may be used (9). Good weed control is also important, since many weeds are alternative hosts for aphids.

Alternative Controls:
Natural Enemies: Aphids may be controlled naturally by parasitic wasps and a variety of predators, including lady beetles and their larvae, lacewing larvae, and syrphid fly larvae. When making a treatment decision, natural enemy populations are considered (8). During periods of high humidity, fungal diseases may also help reduce aphid populations. Many insecticides used in potatoes are detrimental to these beneficial insects (9).

European corn borer

(*Ostinia nubilalis*)

Damage and Life Cycle: The European corn borer overwinters as a mature larva in its burrow in a sweet corn stalk or in the stem of a different host plant (5). Larvae pupate in late April or early May, and adults emerge in late May or early June (11). Female moths lay their eggs on the underside of leaves or on stems (9). A single female can produce as many as 500 eggs during her lifetime (5). Eggs hatch in 4 to 7 days (depending on temperature), and young larvae feed on plant foliage for 7 to 12 days before boring into the stems (11). Stem damage weakens the plant by interfering with translocation of water and nutrients. This insect produces 2 to 3 generations a year in the mid-Atlantic area (11). The stem boring activities of the first larval generation cause the most damage to potatoes in Maryland (9). Insecticide sprays made to control other potato pests in July and August, and the availability of preferred hosts, prevent later generations from causing extensive damage to potatoes (5).

Frequency of Occurrence: The European corn borer feeds on a wide variety of crops and is an early season pest of potatoes in Maryland (5, 14). The timing and extent of damage to the potato crop can fluctuate from year to year and from region to region (12). According to blacklight trap monitoring of adults throughout the state over the past 26 years, the middle Eastern Shore region has the highest average moth activity while the Western part of the state has the lowest. Moth populations can fluctuate considerably, annually as well (13). In general, the European corn borer does not cause any significant yield loss (3).

Management: A degree-day system has been established for predicting the life stages of the first generation. 95 to 100% of potato acreage in Maryland is scouted for European corn borer (3, 29). Scouting begins at 500 degree days and continues through 700 degree days or when egg masses are less numerous. Treatment is suggested if trap catches exceed 100 moths per 5 days (these levels should be reduced if preferred host crops are unavailable) or if 10-25% of the shoots are infested with young larvae or have entry holes. The 10% level applies to fresh market fields, whereas the 25% level is appropriate for processing varieties. Usually one or two well-timed applications of insecticide will keep ECB damage below tolerable levels. The first application is made when thresholds are reached, and an additional treatment may be needed 5 to 7 day later if moth activity exceeds 25 adults per night and additional feeding entry holes are evident (6, 3).

Chemical Controls: Foliar treatments are used to control European corn borer on potatoes (29). Proper timing of foliar insecticide sprays is critical for successful control. The following insecticides are used to control European corn borer on potatoes in Maryland (6):

- **Foliar Rescue Treatments:**
    - cyfluthrin (Baythroid 1.6-2.8 fl oz 2 EC/A) (35).
    - carbofuran (Furadan 1-2 pt 4F/A) (35).

- azinphos-methyl (Guthion 1 qt 2L/A) (35)
- methamidophos (Monitor 1.5-2 pt 4EC/A) (35)
- methyl parathion (Penncap-M 2-4 pt 2FM/A) Less than approximately 2% of acreage is treated (3).
- spinosad (SpinTor 3-6 fl oz 2SC/A) (35). Approximately 15% of acreage is treated for both Colorado potato beetle and European corn borer (3).
  If a pyrethroid (Ambush, Asana XL, Baythroid, Pounce) is used for ECB control, first application is made when 8 to 10 ECB moths are being trapped in local pheromone or blacklight traps. Two to three additional applications are done at 5 to 7 day intervals, based on moth activity (35).
- permethrin (Ambush 3.2-12.8 fl oz 2EC/A or 4-8 fl oz Pounce 3.2EC/A) Approximately 10% of acreage is treated (3).
- esfenvalerate (Asana XL 5.8-9.6 fl oz. 0.66 EC/A) (35). Approximately 5% of the acreage is treated (3).
- permethrin (Pounce 4-8 fl oz 3.2 EC/A) (35)

Alternative Controls:

- Resistant Varieties: Susceptibility to European corn borer damage varies considerably among potato cultivars. Many of the major production varieties can sustain moderate damage without a reduction in yield (9). European corn borer resistant varieties are not used in the mid-Atlantic region (14).
- Cultural Practices: Crop rotation is important. Fields planted in corn the previous year are plowed under, and a cover crop is established in the fall. Cultivation prior to planting as early as possible in the spring is also helpful (5).
- Natural Enemies: There are several natural enemies of European corn borer, but these rarely provide sufficient control. Also, enemy populations are often depleted by the use of insecticides to control European corn borer and other pest species in potatoes (5).

Minor Insect and Mite Pests in Maryland

Potato Flea Beetle

Damage and Life Cycle: Potato flea beetle (*Epitrix cucumeris*) is common throughout the Northeast and is known to transmit early blight and bacterial ring rot. It feeds on a variety of crops, including eggplant, tomatoes, peppers, and potatoes. Adult beetles overwinter in crop debris or weedy areas near fields and become active in early spring. They feed on a variety of herbaceous plants until potatoes emerge. Eggs are deposited on the soil at the base of plants, about 100 eggs per female. Larvae emerge after about 10 days and burrow into the soil, where they feed on roots, sprouts, and tubers, weakening plants and sometimes killing seedlings. They pupate in the soil. Adult beetles emerge and burrow to the surface. They climb onto plants and chew small holes in the foliage which can facilitate the entry of plant pathogens. Beetles may also spread diseases from plant to plant as they feed. The life cycle takes 4 to 6 weeks to complete (5). There are two to three generations per year in Maryland, but only the first generation attacks potatoes (5, 14). Young plants attacked early in the season suffer the most damage (5). Flea beetles do not cause yield loss to potatoes in Maryland (3).

Frequency of Occurrence: Potato flea beetle is a minor occasional pest in our area, but it is usually controlled by insecticide applications made to control other insect pests (3).

Management: Scouting for flea beetles is done early in the growing season, starting at plant emergence (14).

Chemical control for flea beetles is not needed every year, probably due to inadvertent control of beetles by insecticide applications made for other insect pest species (3). Chemical control may be utilized when the first generation population is high, to reduce the potential for disease transmission and prevent later populations from reaching economic levels (5).

Chemical Controls: Chemical control of flea beetles in Maryland is very rare. One entomologist indicated that she knew of only one field where chemical controls were used in the past 10 years. In that case, permethrin and BT were used (14). Imidacloprid applied for control of Colorado potato beetle suppresses flea beetle populations, although the insecticide is not applied specifically for flea beetle control (14).

Alternative Controls: Control of early spring weeds near potato fields and cultivation are used to reduce overwintering and reservoir populations of flea beetles (5).

White grubs
(Scarabidae)

Damage and Life Cycle: White grubs are the larval stage of beetles in the scarab family. They have a broad host range, feeding on over 200 species of plants, including most vegetable crops (5). Females prefer to lay their eggs in fields which have extensive weed growth during mid-summer (16). Larvae hatch during late-summer and move through the soil where they feed on developing tubers, leaving large, shallow, round holes. Since there are no foliar symptoms of grub feeding, beetles may do extensive damage to tubers before the grower is aware of a problem. Damage is usually worst in fields previously planted in sod or pasture (5). White grubs feed and develop as larvae for 1 to 4 years, depending upon the species (16).

Frequency of Occurrence: White grubs are a minor pest of potatoes (14). Like wireworms, white grubs are most commonly found in fields where the preceding crop was sod or other grasses (16). They thrive best in cool, wet soils (9).

Management:

Chemical Controls: No chemicals are used to specifically control white grubs in Maryland (3).

Alternative Controls: No alternative strategies are in place to control white grubs in Maryland (3).

Diseases

Root, Stem, Tuber and Storage Diseases

Common Scab

Damage and Life Cycle: Common scab is caused by a bacterial pathogen called *Streptomyces scabies*, which overwinters in infected seed pieces and in contaminated soils. This pathogen attacks carrots, beets, turnips, parsnips and radishes, as well as potatoes. Soil pH between 5.5 and 7.5 is favorable for bacterial growth, and dry soil conditions during tuber growth promote disease development. This disease has few obvious foliar symptoms but affects tubers with 2 types of symptoms, depending on the variety. Some cultivars develop shallow, cork-like lesions that coalesce to form pits or raised scabs. Other cultivars develop sunken, circular brown lesions. Although there is typically no yield loss (approximately less than 1%) from this disease (33), these symptoms may make the tubers unmarketable (5). Processors can usually accept tubers with raised scabs, but tubers with deep scabs are not suitable for processing (10).

Frequency of Occurence: This disease is not a common problem throughout Maryland. Growers may be controlling it by adjusting pH in their soil (30).

Management:

Chemical Controls: A metiram (Polyram) seed treatment is used to reduce the incidence of this disease (6).

Alternative Controls: Potato varieties vary greatly in their resistance to scab (10). Growers use resistant varieties where possible, as this is the most effective means of controlling the disease (5, 6). In addition, growers use rotation with green cover crops (35). Growers use only disease-free seed and plant into clean soil (5). Growers are careful to provide adequate moisture to the field during tuber development. Soil pH is adjusted downward, where necessary, to inhibit bacterial populations (10).

Bacterial Soft Rot

Damage and Life Cycle: Bacterial soft rot can affect tubers in storage or in the soil prior to harvest. The disease is caused by the bacterium *Erwinia carotovora*, pv. *carotovora*. The pathogen enters the tubers through enlarged lenticels, or through cuts or other areas of previous injury, including damage caused by other diseases (5). The pathogen can also be passed via stolons from an infected plant to its offspring (17). Symptoms develop under moist, warm storage conditions or soil temperatures above 70ºF (5, 10). Lenticels develop sunken brown water-soaked lesions. Infected tissues in the tuber are wet and creamy to tan with dark brown margins. As rot progresses, the infected tissue gives off a foul odor (17). If favorable conditions for disease development persist, all the internal tissue of a tuber may be destroyed (5). Yield loss ranges from 5 to 30%, depending on the weather (33).

Frequency of Occurence: Occurrence depends on weather prior to harvest. Hot, wet conditions are favorable. Soft rot often follows tuber diseases, especially pink rot and insect damage (33).

Management: Wound prevention and packing dry tubers are good management practices (35). A chlorine wash maintained at 25 ppm is beneficial in controlling soft rot. Care is taken during handling, so as not to damage tubers and increase the risk of infection. Tubers in storage may be protected by a 25 ppm chlorine wash (6). However, Maryland does not store potatoes. All potatoes are grown for fresh market or processed for chips. All fresh market potatoes are washed, and chlorine wash is recommended (33).

Chemical Controls: Chlorine wash applied at 25 ppm is recommended (33).

Alternative Controls: Several steps are taken by growers and handlers to reduce the incidence of soft rot. Growers avoid excessive moisture prior to harvest, to lower the rate of lenticel infection. Mature tubers are harvested when soil temperatures are below 68ºF, and care is taken not to damage tubers during harvest and subsequent handling. During and following harvest, tubers are protected from excessive sunlight and dessication. After harvest, tubers are cooled to 50ºF and stored at low temperatures in a dry, well-ventilated area. Tubers are not washed before storage. If they are washed prior to marketing, clean, chlorine-treated water is used, and tubers are dried completely before placement into well-ventilated containers (17).

Leak (Pythium)

Damage and Life Cycle: Leak is caused by the fungal pathogen *Pythium spp.*, which typically enters the plant through mechanical injury, although extremely wet conditions can also promote infection (5, 17). Infection typically occurs at harvesting or grading, though cut seed pieces can also be affected during planting, especially as soil temperatures increase (17). Tubers are the only part of the plant affected by infection, and symptoms usually appear after tubers are placed in storage (5, 17). Discolored, water-soaked spots appear at the site of injury. Infected tubers are swollen, and the skin is moist. Internal rotted tissue is wet and spongy, and appears dark brown to black when exposed to the air, with a dark line of demarcation between healthy and affected tissue. Within a few days, infected tubers may rot completely. The most serious yield losses occur when immature tubers are harvested during hot, dry weather. Poor ventilation and hot weather also promote the disease (17). Yield loss ranges from rare to a maximum of 10% (33).

Frequency of Occurence: When the weather is hot and dry during harvest, leak occurs infrequently (33). Leak causes an approximately 10-15% yield loss. This yield loss usually occurs in regions that harvest during hot weather. Harvesting during this time causes the greatest risk of infection (33).

Management: This disease is managed primarily with fungicides (6).

Chemical Controls: One of the following fungicides is applied with high gallonage of water at flowering. Applications are repeated after 14 days and again after 28 days. Soil coverage at the base of plants is important to assure proper uptake of the fungicide (6). These chemicals are not applied only to control leak; growers treat for pink rot; and the fungicides control both diseases (33).

- mefenoxam + mancozeb (Ridomil Gold MZ 5 lb 68WP/A) Approximately 8% of acreage is treated to control both leak and pink rot (33, 35).
- mefenoxam + copper hydroxide (Ridomil Gold/Copper 2 - 2.5 lb 70WP/A)
- mefenoxam + chlorothalonil (Ridomil Gold/Bravo, Fluoronil 2 lb 76WP/A) (35)
- mefenoxam (Ridomil Gold 4E or Ultra Flourish 0.84 fl oz/1,000 ft of row) This chemical is applied in the furrow at plantingto control both pink rot and leak (33).

An alternative application technique is to apply one of the following in a 6-to-8 inch band directly over the seed-piece prior to row closure (35):

- mefenoxam (Ridomil Gold 0.42 fl oz 4E/1,000 feet of row) or Ultra Flourish (0.84 fl oz 2E/1,000 feet of row) (35)

Alternative Controls: Growers avoid harvesting too early, to allow tuber skins to mature (17). Also, harvesting is delayed in exceptionally warm weather or if the soil is wet (5). Care is taken during harvesting to avoid mechanical injury to tubers. After harvest, tubers are cooled and dried and placed in a well-ventilated storage area. If rotting of stored tubers begins, air flow is increased, and the storage temperature is reduced to 40-45ºF (5, 17).

Pink Rot

(Phytophthora)

Damage and Life Cycle: Pink rot is caused by the fungal pathogen *Phytophthora erythroseptica*. The fungus is soil-borne and can survive for long periods outside of a plant host. Wet weather and warm temperatures promote infection of plants. The pathogen can infect roots and stolons, but tuber decay is the most damaging stage of the disease (10). Foliar symptoms include wilting and necrosis, generally occurring late in the growing season (17). Lesions form on infected roots, stolons and stems, and dieback occurs in severe infections. Tubers may become infected through diseased stolons, or infection may enter the tuber through eyes or lenticels (10, 17). Affected tuber tissue is spongy but not discolored. Infected tubers ooze spore-containing liquid which can spread infection to other tubers in storage (10). Yield loss varies from 2 to 60%, depending on the weather (33).

Frequency of Occurence: Pink rot usually occurs during wet weather close to harvest, on land that has been planted with potatoes without long rotations. It is also more prevalent in low areas and areas that are compacted (spray rows, etc.) (33). Usually yield loss due to pink rot ranges from 5 to 10%; however, on the Eastern shore, yield loss can reach 30% on very susceptible varieties (33).

Management: This disease is managed with a combination of chemical, cultural, and physical controls (6, 10).

Chemical Controls: One of the following fungicides is applied with high gallonage of water at flowering. Foliar applications are normally made twice per season (33). Research indicates that 2 applications with 30 gallons per acre of water yields good control; oil coverage at the base of plants is important to assure proper uptake of the fungicide (6).

- mefenoxam + mancozeb (Ridomil Gold MZ 5 lb 68 WP/A) Approximately 8% of acreage is treated to control both leak and pink rot (33, 35).
- mefenoxam + copper hydroxide (Ridomil Gold/Copper 2 - 2.5 lb 70WP/A)
- mefenoxam + mancozeb (Ridomil Gold MZ 2.5 lb 68WP/A)
- mefenoxam + chlorothalonil (Ridomil Gold/Bravo, Fluoronil 2 lb 76WP/A) (35) Approximately 2% of acreage is treated (33).
- mefenoxam (Ridomil Gold 4E or Ultra Flourish 0.84 fl oz/1,000 ft of row) This chemical is applied in the furrow at plantingto control both pink rot and leak (33).

An alternative application technique is to apply one of the following in a 6-to-8 inch band directly over the seed-piece prior to row closure (35).

- mefenoxam (Ridomil Gold 0.42 fl oz 4E/1,000 feet of row) or Ultra Flourish (0.84 fl oz 2E/1,000 feet of row) (35). Approximately 10% of acreage is treated with Ridomil Gold MZ, Ridomil Gold/Bravo, or Ridomil Gold in the furrow (33).

Alternative Controls: The most important control measure for this disease is growing potatoes on soils with adequate drainage so that soil water does not accumulate around the base of the plants. To avoid rotting of stored tubers, good air flow and low storage temperatures are used. At temperatures below 40ºF, the fungus is dormant (10).

Fusarium Tuber Rot

Damage and Life Cycle: Fusarium tuber rot (also called Fusarium dry rot) is caused by soil borne fungi in the genus *Fusarium. Fusarium roseum* and *Fusarium solani* are the species most often responsible for this disease in potatoes (10). Fusarium rot is primarily a disease of stored potatoes, but may also affect planted seed tubers (10, 17). Fungal spores in the soil or on tuber surfaces can enter tubers through wounds. Fungal growth slowly decays tuber tissue, causing sinking and wrinkling of the skin over the rot. Internal lesions are varying shades of brown, and infected tissue is dry and spongy in texture (10). Cavities may form and tubers may shrivel completely (5, 17). Under damp conditions, secondary infection by bacterial soft rot is common. Lesions invaded by these bacteria become slimy and take on a foul odor. Fusarium rot develops slowly. Early symptoms typically occur about 1 month after tubers are placed in storage (10). Yield loss ranges from 2 to 10% (33).

Frequency of Occurrence: Fusarium dry rot occurs on potatoes worldwide (17). It is not generally a problem on processing potatoes, which are not stored but go directly to the processor for chipping (30).

Management: This disease is managed primarily with careful harvesting, handling and storage practices to prevent tuber wounds and limit fungal activity (10). Seeds treated with a fungicide prior to storage are used (6).

Chemical Controls: Maryland growers used to treat the seeds with thiabendazole (Mertect 340F at 1,500 ppm), prior to storage (6, 33). Since the fungus developed resistance to Mertect, treated seed is almost non-existent (33). Approximately 5% of acreage is treated with thiabendazole (33).

Alternative Controls: Tubers are allowed to fully mature before harvest, and care is taken to reduce wounding (10, 17). High humidity and good ventilation early in storage are used to promote healing (17).

Verticillium Wilt

Damage and Life Cycle: Verticillium wilt is caused by either of two fungal organisms, *Verticillium albo-atrum or Verticillium dahliae* (17). The fungi commonly inhabit the soil and may also be found on old infected tubers (10). Inoculum can be carried in infected soil transported by equipment, spread in irrigation water, on air currents, or by root contact between adjacent plants. This disease is characterized by wilting of plants during the growing season (17). Young infected plants are stunted, and may wilt and die (5). Older plants turn yellow and die due to early senescence (5, 17). The rate of senescence depends upon soil moisture level; death is more rapid in damp soils. Leaf yellowing and wilting starts at the base of the plant and moves upward. Necrosis and curling of leaves may also occur (5). Tubers from surviving infected plants often have a pale brown discoloration of the vascular ring. Cavities can form in severely affected tubers (17). This disease is particularly severe when soil populations of lesion nematodes (*Pratylenchus penetrans*) are high (5). Yield loss ranges from 5 to 20% (33).

Frequency of Occurence: Verticillium wilt is one of the most damaging diseases of fresh market potatoes in Maryland (10). The disease is widespread, occurring wherever potatoes are grown (17). This disease is not yet a major problem in processing potatoes, perhaps because this is a relatively new crop in our area, and Verticillium populations in the soils have not reached damaging levels. The pathogen was detected in a commercial field of processing potatoes for the first time in 1998 (30).

Management: This disease is managed mainly by crop rotation and the use of resistant varieties where possible

(6).

Chemical Controls: Fumigants and nematicides applied for nematode control help to reduce Verticillium populations in the soil. When nematode counts are high enough to warrant such a treatment, it is generally done preceding a vegetable crop in the rotation with potatoes (30). Metam-sodium (37 gal/A Vapam HL or Busan) is applied to approximately 1 to 2% of acreage, by center pivot irrigation systems to fallow fields in the fall (33). Mocap (30 lb 10G/A) is applied to approximately 5% of the acreage to reduce populations of lesion nematodes to lessen the severity of the disease (6). 1,3-dichloropropene (Telone) is used commonly in Dorchester County for nematode control in rotational vegetable crops (30). These products are not applied to control verticillium unless there are some concerns about nematodes as well (33).

1,3-dichloropropene (Telone) is applied on approximately 1 to 2% of acreage (33).

Alternative Controls: Resistant cultivars are used wherever possible (6). Crop rotation and other agronomic practices that control nematodes also reduce Verticillium wilt. Crop rotation is the most important cultural practice, since it reduces inoculum levels of the soil-borne pathogen and is widespread (17, 30). Rotations to certain unrelated non-host crops, especially sudangrass and other grasses, cereals, and legumes, are most effective. There is an increased interest in the use of these rotations as an alternative control strategy (6, 17, 30). Rotations to peppers, tomato, or eggplant are avoided, since they are alternate hosts for lesion nematode and are especially susceptible to Verticillium wilt (6, 30).

Primarily Foliar Diseases

Early Blight

Damage and Life Cycle: Early blight affects both the foliage and the tubers of potato plants, particularly those that are older or stressed. It is caused by the fungus *Alternaria solani*, which overwinters in the soil and on refuse of potatoes and related plants in the field. Spores come in contact with leaf tissue and germinate under moist conditions. The fungus penetrates leaf tissues long before symptoms become apparent. Foliar symptoms most often appear soon after flowering, and are usually first observed on older, lower leaves. Brown leaf lesions with concentric rings surrounded by a yellow margin characterized the early foliar phase. Lesions become angular where fungal growth is limited by veins. As the disease spreads, lesions appear on younger, higher leaves, and dark lesions may also appear on the stems (10). Tuber infections may occur at harvest when soil dwelling spores come in contact with tubers. The fungus requires moisture on tuber surfaces to initiate infection, and can enter mature tubers through wounds or lenticels (which are open when the tuber surface is wet). Immature tubers and those harvested from coarse sandy soils under wet conditions are more susceptible to infection (10). Circular or irregular dark lesions, often with a purple border, are visible on the skin. The tissue below is typically brown, dry and corky, but becomes yellowish and water soaked in the later stages of infection (17). Yield loss ranges from 1 to 5% (33).

Frequency of Occurrence: Early blight occurs worldwide where potatoes are grown. Spread of the disease is favored by alternating wet and dry conditions. In severe foliar infections, tuber yields may be significantly reduced (10). Early blight is not a large concern for most Maryland growers, except where susceptible cultivars, such as Belrus and Conestoga, are grown (30).

Management: This disease is managed with resistant cultivars and a combination of chemical and cultural controls (6, 10, 30).

Chemical Controls: Chemical applications made for control of late blight, a more significant disease problem in Maryland, offer some protection against early blight infection (30). Growers begin sprays in mid-June and continue every 7 to 10 days unless there are threats of late blight. Usually the number of applications depends on disease pressure (33). If that is the case, then applications begin when plants are 8 inches tall. Growers choose one of the following products (6):

- chlorothalonil (Bravo, Echo, Equus 1-1.5 pt 6F/A)
- chlorothalonil (Bravo Zn 1.5-2.13 pt 4F/A) Approximately 30% of acreage is treated (33).
- copper, fixed (1.5 lb 61DF/A) (35)
- mancozeb (Dithane, Manzate Manex II, or Penncozeb l.5-2 lb 80WP/A) Growers do not apply more than a total of 15 pounds of mancozeb or Polyram per acre per crop. Approximately 80 to 85% of acreage is treated (33, 35).
- metiram (Polyram 2 lb 80DF/A) Growers do not apply more than a total of 15 pounds of mancozeb or Polyram per acre per crop. Approximately 15% of acreage is treated (33, 35).
- triphenyltin hydroxide (Super Tin 6 fl oz 4L/A) + mancozeb (Dithane, Manex II, Manzate, Penncozeb 2 lb 80WP/A) Approximately 5% of acreage is treated (33).
- azoxystrobin (Quadris 6.2-12.4 fl oz 2.1F/A) (33, 34, 35)
- iprodione (Rovral 2 lb 50 WP/A) (35)
- Approximately 20% of acreage is treated with chlorothalonil, metiram, triphenyltin hydroxide, or Quadris (33).

Alternative Controls Good cultural practices often are enough to prevent economic losses from early blight. Any management practices that reduce plant stress, including fertility management, also reduce the occurrence of early blight. Tubers are not harvested until about 2 weeks after vine kill, when they are fully mature. Harvesting under wet conditions is avoided, and care is taken during harvest to avoid tuber injury. Forced air is used to dry tubers placed in storage, and rapid wound healing is promoted (10).

Late Blight

Damage and Life Cycle: Late blight is a potentially devastating foliar disease which also infects tubers. Late blight is caused by the fungal pathogen *Phytophthora infestans*, which overwinters in infected tubers left in the field in cull piles. Shoots from these tubers are a source of inoculum early in the growing season (5). Temperatures below 78ºF combined with high humidity or abundant water from irrigation or rainfall provide conditions for disease development. Spores spread to new plants, causing small water-soaked lesions at leaf tips or margins. Lesions expand and turn dark brown or purplish-black, with green, water-soaked margins. If conditions remain favorable, spore-producing white mycelium appear at the margins of the lesions, particularly on the underside of the leaves. The stems of infected plants develop dark lesions and may wilt and die. The disease tends to spread across the field in a tear-drop pattern originating from the first infected plant (10). Tubers become infected when they come in contact with spores deposited on the soil from infected foliage (17). Even when foliar infections are minimal, significant damage to tubers can result. Irregular brownish-purple lesions of variable size with black margins appear on the tuber surface (10). A brown granular rot which lacks a distinct margin penetrates a short distance (< 2 cm) into the tissue (10, 17). Under improper storage conditions with abundant moisture, infection may spread to other tubers, and secondary infections of bacterial soft rot may follow (10).

Frequency of Occurence: Late blight is probably one of the most important and damaging diseases of potatoes worldwide (17). It does not occur every year in Maryland, and when it does, it is often associated with infected seed pieces (30). Infections of late blight can occur as early as June, while before early blight (5). Late blight has not occurred in Maryland since 1995 or 1996 (33).

Management: This disease is managed with preventive fungicide sprays and a combination of cultural and mechanical management strategies (6, 10). Late-blight forecasting models are used in the East to determine the timing of protective fungicide applications (10). These models are used by many Maryland growers (30).

Chemical Controls: During cool, wet weather, when disease development is favored, growers apply one of the following protective fungicides. The first application is made when plants are 6 inches tall, and treatment is repeated every 7 days, as long as conditions for disease development remain favorable (6). Alternatively, the timing of applications may be determined by following the disease forecasting model (30). The following protective fungicides should be applied early in the season prior to the occurrence of any disease in the region (35):

- chlorothalonyl (Bravo, Echo, Equus 1-1.5 pt 6F/A
- azoxystrobin (Quadris 12.4-15.4 fl oz 2.1 F/A) Quadris is more expensive than most of these other products (30). Quadris is not used for late blight when the disease occurs alone, but since it controls early blight, it is used when both diseases are present at the same time (33).
- chlorothalonil (Bravo, Terranil 1-1.5 pt 6F/A) Approximately 15% of acreage is treated (33).
- cymoxanil (Curzate 3.33 oz 60DF/A) This is used only in combination with a protectant (e.g., chlorothalonil or mancozeb).
- dimethomorph + mancozeb (Acrobat MZ 2.25 lb 69 WP/A)
- mancozeb (Dithane Manex II, Manzate Penncozeb l.5- 2 lb 75 DF/A) Growers do not apply more than a total of 15 pounds per acre per crop. Approximately 80% of acreage is treated (33, 35)
- mancozeb + zoxamide (Gavel 1.5-2 lb 75DF/A)
- metiram (Polyram 2 lb 80DF/A) Growers do not apply more than a total of 15 pounds per acre per crop. Approximately 5% of acreage is treated (33, 35).
- propamocarb HCL (Previcur Flex 0.7-0.9-1.2 pt SL/A) Rates are listed in order for low-medium-high disease risk situations. This chemical is used only in combination with a protectant fungicide; e.g., chlorothalonil or mancozeb or azoxystrobin.

The only products being used are mancozeb, Bravo and Polyram as protective fungicides. If late blight were to occur, the other products would be used. As for early blight, all the acreage would be treated with those same products along with Quadris (33).

Resistance Issues: New strains of *Phytophthora infestans* are present in the mid-Atlantic region. These strains are aggressive on potatoes and are resistant to Ridomil Gold (6).

Alternative Controls: Cultural control practices include planting resistant cultivars where possible, crop rotation, the use of certified seed, and removal of cull piles and debris from the previous year's crop (10, 30). Volunteer plants, a potential source of inoculum are removed or killed with herbicide. Tuber infection is minimized by hilling to keep tubers covered at all times (10). When a field contains new late blight infections and harvest is near, vines are killed immediately and tubers are not harvested until 2 weeks later, allowing time for spores on the foliage to die (6, 10). Harvesting under wet field conditions is avoided. To prevent tuber infection from spreading in storage, good ventilation and the lowest possible temperatures are used (10).

White Mold

Damage and Life Cycle: White mold, a cool temperature disease, is caused by the fungal pathogen *Sclerotinia sclerotiorum*, and to a lesser extent by *S. mino* and *S. intermedia* (17). It affects crops as diverse as beans, carrots, alfalfa, and lettuce (10). The fungus overwinters in the soil as sclerotia, an irregularly shaped, hard, black life-stage (17, 10). In the presence of adequate moisture at temperatures above 60ºF, sclerotia germinate spore-producing structures called apothecia on the surface of the soil. Spores released infect plants locally, or may travel great distances on the wind. If free moisture is available for 48 hours, spores will infect plant tissue. White, water-soaked lesions appear on the stems and leaves, and a white mold develops (10). In advanced infections, stems may be girdled, killing the plants. Tubers may be infected if they are near the soil surface. Tuber flesh becomes blackened and spongy. A soft, white rot forms inside the tuber, which in advanced stages may develop mycelium-filled cavities (17). This disease does not result in any yield loss (33).

Frequency of Occurence: This disease is uncommon on potatoes in Maryland (30).

Management: This disease is managed with a combination of cultural controls and fungicide sprays (6, 10).

Chemical Controls: Potatoes are not treated for white mold (33).

Alternative Controls: Proper fertilization and careful water management are important for the control of white mold. Growers avoid application of excessive nitrogen and time irrigation so that the leaves are not wet for 48 hours at a time (10).

Rhizoctonia Stem Canker

Damage and Life Cycle: Rhizoctonia stem canker is caused by the fungus *Rhizoctonia solani*. This pathogen attacks a variety of crops and weeds; however, the specific strain that attacks potatoes does not infect other crops (10, 17). Stem canker affects both the foliage and the tubers of potato plants (5,10,17). This disease attacks underground stems, shoots and stolons (5). Wet, cold weather and poorly drained soils promote infection of plants, especially during shoot preemergence (10, 17). Temperatures around 64F or below are optimum conditions for disease development (10, 17). The pathogen enters the stems and sprouts through wounds; later in the season, the pathogen infects roots and stolons (17). Under cool and wet environmental conditions, sclerotia will be formed on the surface of the tubers (10). The dark sclerotia that forms on the tuber surface is known as "black scurf" (10). The sclerotia may make the tubers unmarketable (5). The most common symptoms are reddish-brown lesions on underground parts of the stems and stolons, whitish stems, formation of aerial tubers at the base of the stems and damage to the vascular system (10). When the vascular system is damaged, this results in foliar symptoms, including wilting, stunting, curling, and yellowing (10). This disease may cause yield reduction (5).

Frequency of Occurrence: Occurrence depends on the weather; cold and wet soils promote the spread of the disease (10). Usually this disease does not result in high yield loss, unless the environmental conditions are cool and wet (10).

Management: This disease is managed mainly with cultural practices (5).

Chemical Controls: Seed pieces are dusted immediately after cutting. Some fungicide seed-piece treatments are formulated with fir or alder bark. Bark formulations have been effective treatments. Growers use one of the following (34):

- captan (l lb 7.5D)
- fludioxonil (Maxim - 0.5 lb 0.5D)
- flutolanil+mancozeb (MonCoat MZ - 0.75 lb 7.5D)
- maneb (Manex 1 lb 8D)
- metiram (Polyram 1 lb 7D)
- thiophanate-methyl (Tops - 1 lb 2.5 D)
- thiophanate-methyl (Tops MZ - 0.75-1 lb 8.5D) (35)

Alternative Controls: Several steps are taken to reduce the incidence of stem canker. Growers avoid planting when the soil is cold (below 45F) or wet (10). The use of only disease-free seed reduces the risk of developing the disease (5, 10, 17). Another effective control mechanism is to use cultural practices that promote fast sprout emergence (10). Crop rotations are done with grasses and cereals; however, sugar beet, alfalfa, or clover are avoided (5, 10). The use of shallow seedpiece covering accelerates the emergence of shoots in the spring (5).

Fusarium Seed-Piece Decay

Damage and Life Cycle: Fusarium Seed-Piece Decay is caused by the fungus *Fusarium sambucinum* (5). Hot and dry soils promote the infection of seedpieces (5). The pathogen enters the seedpieces following planting (5). First symptoms are reddish-brown to black spots (10). As the disease progresses, the affected area turns black, gets thin, sinks, shrinks, and finally rots (5,10). Other symptoms include stunting and necrosis of the shoots as well as heterogeneous plant size (5, 10).

Frequency of Occurrence: Seed piece decay occurs worldwide where potatoes are grown (10). Environmental conditions, such as cool, extremely wet or dry soil, promote the development of this disease (10).

Management: This disease is managed primarily with careful seed handling and planting (10).

Chemical Controls: Seed pieces are dusted immediately after cutting. Some fungicide seed-piece treatments are formulated with fir or alder bark. Bark formulations have been effective treatments. Growers use one of the following (34):

- >captan (l lb 7.5D)
- fludioxonil (Maxim - 0.5 lb 0.5D)
- maneb (Manex 1 lb 8D)
- metiram (Polyram- 1 lb 7D)
- thiophanate-methyl (Tops - 1 lb 2.5 D) (35)

Alternative Controls: Seedpieces are dried for several days in a well-ventilated place (5). This procedure is important for adequate suberization (5). Suberized seedpieces are immune to the disease (10). It is very important to plant seedpieces under adequate conditions for fast suberization (10). First, all the cutting and handling equipment is sanitized; then seed tubers are warmed to 50F, cut and planted (10). Optimum planting conditions are soil moisture that ranges between 60 to 80% and soil temperature above 45F. Irrigation is done after plant emergence (10).

Nematodes

Nematodes are extremely common, tiny (less than 0.25 inches long), nonsegmented roundworms, many of which are soil-dwelling. Plant parasitic nematodes complete their life cycle by feeding on living plants, most often the roots. They may feed on plant tissues from the inside (endoparasitic) or from the outside (ectoparasitic), and their feeding activity may interfere with nutrient uptake or stimulate physiological changes that disrupt healthy plant functions (7, 16).

Several species of plant pathogenic nematodes occur in Maryland soils (6), generally as mixed populations unevenly distributed throughout a field (16). Of these, the most important species on potatoes in Maryland are root knot nematodes and root lesion nematodes (5, 18). There are several ways nematodes may cause damage to the potato crop. Root feeding may cause a reduction in plant growth, stunting, a general loss of vigor, and increase host susceptibility to bacterial or fungal infections (7, 17). Certain nematodes may also serve as vectors for pathogenic viruses (7), but there are currently no known viruses of economic importance in Maryland (19). Any of these factors can cause a significant reduction in yield (20). Some nematodes may also disfigure tubers directly, making them unmarketable (7).

Because potato production is relatively new in Maryland, the economic importance of nematode populations has not been fully assessed. At present, no yield loss of potatoes is directly attributed to parasitic nematodes (19). However, high levels of nematode damage frequently occur on the crop that follows potatoes. Growers are increasingly concerned that potatoes, which often replaced small grains (a non-host) in rotation with vegetables and other crops, are contributing to a build-up of damaging levels of nematodes in the soil (30). Researchers are currently evaluating nematode monitoring practices in the state, and planned studies include the role of crop rotation on nematode populations and potato yield (19).

Root Knot Nematodes

Damage and Life Cycle: Among the most important potential nematode pests of potatoes in Maryland are root knot nematodes (*Meloidogyne spp.*) (19). Like most nematodes, they have a broad host range, and feed on a variety of crops and weeds (21). Root knot nematodes are sedentary endoparasites, attaching themselves within root tissue and feeding from a single location (7). The life cycle and plant pathogenicity is similar for *Meloidogyne* species on all crops (21). In our area, nematodes overwinter in the egg stage in root galls or in the soil (5). The second-stage juvenile invades the roots, feeding within the vascular system by piercing cell walls with its stylet (21). Secretions exuded by nematodes during feeding cause plant cells to swell, producing the diagnostic elongated or rounded "knots" on the roots (21, 22). The location, size, and shape of galls vary, depending on nematode species and host plant variety (7, 19). Nematodes feed within the plant and undergo 3 more molts before reaching reproductive maturity. Females produce eggs in a gelatinous sac attached to their posterior end. Juveniles develop and undergo one molt within the egg before emerging to continue the cycle (21). Generation time is 25 to 40 days, depending upon host susceptibility, moisture, temperature, and soil type (19, 23). Root knot nematode populations build up on potatoes. While potatoes are not in the ground long enough to be affected greatly, populations do affect crops such as cucumbers or soybeans (32).

Above-ground symptoms of root knot nematode infestation include stunted and wilted plants and chlorosis. The extent of these symptoms is dependent on the population density of nematodes and on environmental conditions (20). The worst damage occurs when high temperatures combine with low soil moisture (5). Nematode feeding produces the most severe symptoms under drought conditions, when plants are under increased stress (19). Yield reductions are highly variable, but can be significant. Also, the presence of nematodes has been associated with an increased rate of infection by fungi or bacterial pathogens, which can further reduce yield. Under favorable environmental conditions, warty galls may be formed on the tubers if high levels of root knot nematodes are present (17), though there are no reports of significant damage in Maryland (19).

Frequency of Occurrence: Root knot nematodes are widespread and attack a large number of crop plants. They are a potentially serious pest of potatoes in Maryland, although at present no yield loss has been directly attributed to these nematodes. Populations tend to be highest, and outbreaks more likely in light, sandier soils as opposed to heavier clay soils (19). Dorchester County experiences high levels of nematodes because soil conditions there are favorable (30). Population levels are prone to drastic fluctuations (19).

Potatoes are good hosts causing increased populations. While yields don't seem to be affected, subsequent crops can be damaged. Fumigation following potatoes is often done to reduce populations to tolerable levels for rotational crops (32).

Management:

Chemical Controls: Many growers fumigate to reduce populations and follow about a three-year schedule (32).

Alternative Controls: Work is now being done to find alternative controls by planting crops that will reduce nematode populations (32). Preliminary field plot studies have indicated that root knot nematode populations probably can be managed if non-host crops are used to interrupt the life cycle of the root knot nematode (37).

Root Lesion Nematodes

Damage and Life Cycle: Root lesion nematodes (*Pratylenchus* spp.) have a broad host range, and at least 15 different species are reported to attack potatoes. All species are endoparasitic and migratory, spending some time in plant tissues and some time in the soil. All life stages starting with second-stage juveniles puncture and penetrate the roots of potatoes, where they may feed for a variable length of time. Extensive feeding causes cell death. Unlike root knot nematodes, root lesion nematodes will abandon damaged tissue, finding new cells to infect (20). Eggs are deposited inside root tissue or in the soil. Eggs hatch as infective second stage juveniles (7). Several overlapping generations occur per growing season, and all stages can overwinter in our area (19, 20).

Foliar symptoms are not obvious. Plants may be stunted and yellowed in some areas of the field. Dark brown to reddish root lesions indicate where tissue has been infected. Tuber infections, marked by sunken lesions or scabs, are also caused by some of these nematode species. Tuber symptoms can vary considerably, depending on the *Pratylenchus* species involved (20).

Root lesion nematodes can interact with the fungal pathogen that causes Verticillium wilt to produce a disease known as "potato early dying." The interaction between the nematodes and the fungi is synergistic, initiating the disease at population densities of nematodes and fungi that would be of little significance on their own (20).

Frequency of Occurrence

Root lesion nematodes cause economic damage to potato crops throughout the Northeast (20). However, root lesion nematode damage to the Maryland potato crop is currently low. This could be due to the fact that processing potatoes are a relatively new crop in Maryland, and nematode populations have not yet reached economic levels. This nematode poses a potentially serious threat to potato production (30). The root lesion nematode does not occur frequently, and, if it does occur, it is often undiagnosed (33).

Nematode Detection: Researchers are currently evaluating nematode detection practices in the state, as sampling procedures need improvement (19). Ideally, nematode management should be considered prior to planting. Samples are taken from fields after harvest but before tillage, when nematode populations are generally highest, to determine if nematodes are present in a field and to plan the cropping sequence (16). If nematode damage is suspected after crop emergence, soil and root samples are submitted for laboratory analysis to determine the kind and number of nematodes present (6).

Nematode Management:

Resistant Varieties: Nematode resistant potato varieties are not available to Maryland growers (17, 30).

Crop Rotation: Crop rotation is a useful strategy for maintaining low populations of many nematode species, although nematode pests with a broad host range severely limit crop rotation options (17). The length of rotation and the cropping sequence which are most effective will depend upon the nematode species present (7). Rotation to corn or cereal decreases the potential for root knot nematode problems and also helps to control a variety of diseases. Rotation into sorghum is especially effective for reducing root knot and other nematode populations, and some growers do this (24). Maryland growers generally rotate 1 to 2 years away from potatoes (30). Vegetable crops are common in some rotations (32). However, because many weeds and volunteer potatoes serve as alternate hosts, rotation does not always provide sufficient suppression of root knot nematodes (5, 30). Crop rotation is not an effective control measure for root lesion nematodes, because of their extremely broad host range. Rye is a particularly suitable host for root lesion nematodes, and population outbreaks can result from the use of rye cover crops (17). Land limitations and market demands are also factors which can limit the usefulness of crop rotation as a control measure for nematodes or diseases (25). Crop rotation practices in Maryland are currently being evaluated (19).

Other Management Practices: Other practices that help to prevent the build-up of nematodes include the use of uninfected seed pieces, cleaning of farm equipment, avoiding reuse of irrigation water, and maintaining good weed control (7). Use of green manure, cover crops, and soil amendments can help to decrease populations of root knot nematode by maintaining crop plant vigor and promoting populations of nematode natural enemies (26). Post-harvest disking and allowing fields to remain fallow are two common practices that help to reduce soil populations of nematodes (6, 27, 30, 32).

Chemical Controls: Chemical controls available for nematodes include volatile fumigants and nematicides. Chemical control may effectively reduce populations for a limited time, but populations quickly rebound after the chemical wears off (28). Chemical controls are used in combination with crop rotation and cultural practices to minimize nematode damage. In Maryland, ethoprop (Mocap 30 lb 10G/A) is applied in a 12-inch band at planting (6) and is used on approximately 5% of acreage (33). When nematode counts are high enough to warrant such a treatment, it is generally done preceding a vegetable crop in the rotation with potatoes. The reason for this timing is that potatoes are planted early in the spring and application of a soil treatment would cause a delay in planting. Vegetable crops are planted later, giving the grower a bigger window with which to get in, fumigate, and get the vegetables planted (30).

Weeds

Weeds cause economic loss in potatoes in several ways. These include competition for nutrients, space, water and light, which will reduce yields; and a reduction in the efficiency of harvesting. Weeds may also act as reservoirs for insect pests and diseases. Most weeds produce numerous seeds, many of which can remain dormant in the soil for years. As a result, weed infestation may cause problems for years. Therefore, proper weed management is essential not only for this year's crop, but also for years to come (7).

Major Weeds of Potatoes

Table 1: Major weeds in potatoes

species	avg. annual % yield loss*	avg. % control for weed*
Pigweed, Smooth	2	98
Ragweed, Common	3	95
Annual Grasses	0	100
Cocklebur	1	95
Nutsedge, Yellow	5	90
Morningglory, Annual	1	90

*With current cultural practices and herbicide use.

Weed Management:

Non-chemical Controls: Herbicides are used in conjunction with cultivation and cultural control practices to achieve good weed control in potatoes. Where possible, growers select cultivars that compete well with weeds, and plant rows close together to discourage weed growth (5). Weeds from previous crops in the rotation are reduced by the use of certified seed for all crops in the rotation. The spread of weeds from one field to another is minimized by cleaning farm equipment between uses in different fields. Maintaining good weed control around field borders and fence rows is important, as these are a potential source for insect pests and disease as well as weed seeds. Growers plant competitive grasses at field borders and keep these areas free of weeds. Well-planned crop rotations are also an important strategy growers use to reduce weed pressure (7).
Cultivation is a critical part of weed management in potatoes, but it must be done with great care to avoid damage to the tubers and plants and cause yield loss. Fields must be cultivated several (at least three) times while the target annual weeds are small, to achieve effective control (7, 31). Multiple cultivations form a hill over the row and provide effective control against weeds. Also, early planting in March provides early growth, and crop canopy development before weeds emerge and will suppress weeds. Grass is probably the most difficult to

control by cultivation (31).
Scouting - Most growers scout for weeds (31). Fields are scouted to identify the weeds in each field and to select recommended herbicides that control those weeds (6). Scouting is done within 4 weeks of crop emergence to determine the effectiveness of preplant incorporated and preemergent herbicides. Scouting can determine if a postemergent product is needed, what products should be used, and assure that the application is made while weeds are still small and susceptible. Fields are scouted again 4 or 5 weeks before vines mature to determine if weeds will interfere with harvest. Scouting also helps to plan weed control strategies for harvest and the next cropping season (5, 31).

Chemical Controls:

1. Preplant Incorporated and Preemergent Herbicides - Preplant incorporated and preemergence herbicide selection is based on the weed species present in the field, the soil type, and the percent of organic matter in the soil (6).
   - **EPTC --**Growers apply 3 - 4.5 lb ai/A (3.4 - 5.1 pt/A of Eptam 7E or 30 to 45 lb/A of Eptam l0G) just prior to the first or second cultivation (this treatment is best for late-season control of nutsedge and other weeds). EPTC is not applied within 45 days of harvest. This herbicide is used by about 2% of the growers (6, 31).
   - **Linuron--**Growers apply 0.4 - 1 lb ai/A (0.8 - 2 lb/A Lorox 50DF) after planting or before potatoes emerge, but after final drag-off and before grasses are 2 inches tall and before broadleaf weeds are 6 inches tall. Linuron mainly controls broadleaf weeds, is seldom applied alone, and is tank-mixed at low rates with s-metolachlor or pendimethalin, or used in addition to EPTC for preemergence annual grass control. Lower rates of linuron are used if tank-mixed (6, 31). On approximately 90% of the acreage, one application of Linuron is used in combination with s-metolachlor (31).
   - **S-Metolachlor--**Growers apply 1-2 lb ai/A (1-2 pt/A of Dual Magnum (7.6 E)) before potatoes emerge, but after final drag-off. Nutsedge control may be adequate if weed pressure is light. S-metolachlor is seldom applied alone, but is tank-mixed with linuron or metribuzin for broadleaf weed control on approximately 90% of the acreage (6, 31).
   - **Metribuzin --**Growers apply 0.25 - 0.66 lb ai/A (0.33 lb/A of Sencor 75DF or comparable rates of liquid formulation) just prior to emergence. Metribuzin primarily controls broadleaf weeds and is tank-mixed with s-metolachlor as a post drag-off treatment for preemergence annual grass control on approximately 20% of the acreage (31). Metribuzin is not applied within 60 days of harvest (6).
   - **Pendimethalin--**0.5-1.5 lb/A. Growers apply 1 to 3 pt/A of Prowl 4EC before potatoes emerge. Prowl primarily controls certain broadleaf weeds, including velvetleaf and early-season annual grasses. Pendimethalin is combined with Lorox to improve velvetleaf control, or with linuron or metribuzin to improve the control of most other broadleaf weeds. Pendimethalin is used on approximately 5% of acreage (35).
2. Postemergence Herbicides - Growers apply postemergence herbicides when crop and weeds are within the recommended size and/or leaf stage to maximize weed control and minimize crop damage (6).
   - **Rimsulfuron--**Growers apply 0.0156 lb ai/A (1 oz/A of Matrix 25DF) soon after emergence to control many weeds, including wild mustard and wild radish. Rimsulfuron is usually applied once on approximately less than 10% of the acreage. This product may be tank-mixed with reduced rates of metribuzin to increase the spectrum of weeds controlled, such as lambsquarters (31). Results tend to be most effective when used following a preemergence residual weed control program. To improve weed control, growers add nonionic surfactant to be 0.25% of the spray solution (1 quart per 100 gallons of spray solution). Rimsulfuron is an ALS inhibitor and is always used in combination with other herbicides with different modes of action to prevent the development of

resistant weed populations (6).

- **Metribuzin** --Growers apply 0.25 - 0.5 lb ai/A (0.33 - 0.66 lb/A of Lexone or Sencor 75DF) before weeds are 1 inch tall. Metribuzin mainly controls broadleaf weeds. It is used on approximately 20 - 30% of the acreage as a postemergence treatment. Rain can wash away the wax layer that is necessary to protect the potato leaves from the treatment, so metribuzin is applied only if there have been at least three successive sunny days prior to application. The sun will also give the plant extra energy to withstand the application. It is not used on red-skinned or early maturing, smooth, white-skinned varieties because it can cause delay of tubers and a late harvest which can miss the price premium for new potatoes (31). Treatment can cause some yellowing or minor burn (6).
- **Clethodim** --0.094- 0.125 lb/A. Growers apply 6 to 8 fl oz/A of Select 2EC with oil concentrate to be 1% of the spray solution (1 gallon per 100 gallon of spray solution) postemergence to control many annual and certain perennial grasses, including annual bluegrass. Select 2 EC will not consistently control goosegrass. The use of oil concentrate may increase the risk of crop injury when hot or humid conditions prevail. To reduce the risk of crop injury, additives are omitted or switched to nonionic surfactants when grasses are small, and soil moisture is adequate. Control may be reduced if grasses are large or if hot, dry weather or drought conditions occur. For best results, annual grasses are treated when they are actively growing and before tillers are present. Repeated applications may be needed to control certain perennial grasses. Wild onion will not be controlled. Tank-mix should not be applied within 2 to 3 days of any other pesticide unless labeled, as the risk of crop injury may be increased, or reduced control of grasses may result. Minimum preharvest interval of 30 days must be observed (35). Clethodim is applied to approximately 2% of the acreage (31).
- **Sethoxydim**--Growers apply 0.2 - 0.3 lb ai/A (1 - 1.5 pt/A Poast 1.5EC with oil concentrate added to be 1% of the spray solution) in one application after emergence. It is applied on approximately 5% of acreage (31). For best results, growers treat annual grasses when they are actively growing and before tillers are present. Control may be reduced if hot, dry weather or drought conditions occur. Repeated applications may be needed to control certain perennial grasses. Wild onion is not controlled by sethoxydim. Growers do not tank-mix with or apply within 2 to 3 days of any other pesticide unless labeled, as the risk of crop injury may be increased, or reduced control of grasses may result. No more than 5 pt/A of Poast is applied during the growing season, and a minimum preharvest interval of 30 days is observed (6).

3. Postharvest -
    - **Glyphosate**--Growers apply 2 - 5 lb ai/A (2 - 5 qt/A of Roundup Ultra 4SC) in the fall after harvest to control perennial grasses and broadleaf weeds, including quackgrass, field bindweed, Canada thistle, and others. (Rate varies depending on the weed population). Application is delayed after harvest (but applied prior to the first frost) to allow for adequate weed regrowth to intercept the spray. Growers do not till or mow for 1 week after application (6). Glyphosate is not used on the Eastern Shore; however, it is used in low amounts in Garrett and Allegany counties for thistle or quackgrass control. Approximately 1 to 2% of the acreage is sprayed for perennial weeds with glyphosate (one application of 1.5 lb ai/A per season). This product is not used for either fresh market or processed potatoes; however, it is used in approximately 1% of acreage in storage (late harvest-October-November) (31).

Chemical Control Issues for Herbicides: Triazine resistant lambsquarters and redroot pigweed are tolerant to metribuzin and may be a problem in the future as they spread across Maryland. Although EPTC is not used, it could be an effective alternative treatment for the triazine-resistant lambsquartersand pigweed. S-metolachlor does not control lambsquarters, but it is effective for triazine-resistant pigweed. Rimsulfuron could be an effective alternative for triazine resistant lambsquartes and pigweed; however, sulfonylurea resistance seems to develop rapidly in some weed species, and adequate alternative herbicides must be retained for control of potential sulfonyl tolerant weeds.

Table 2. Potato herbicides for grasses and sedges.

	GRASSES AND SEDGES						
Herbicide	Barnyard-grass	Crabgrass, Large	Fall Panicum	Foxtail sp.	Goosegrass	Johnsongrass (seedling)	Yellow nutsedge
Preemergence or Preplant Incorporated:							
EPTC	G	G	G	G	G	G	G
Preemergence:							
linuron	F	P/F	P	F	P/F	-	N
s-metolachlor	G	G	G	G	G	G	F/G
metribuzin	F	F	F	F	F	-	N
pendimethalin	G	G	G	G	G	G	N
Postemergence:							
clethodim	G	G	G	G	P	G	N
rimsulfuron	G	P/F	F/G	G	P	-	F
metribuzin	F	F	F	F	F	-	-
sethoxydim	G	G	G	G	G	G	N

Herbicide performance is affected by weather, soil type, herbicide rate, weed pressure and other factors. These ratings indicate ONLY relative effectiveness in tests conducted by the University of Delaware, University of Maryland System, The Pennsylvania State University, Rutgers, The State University of New Jersey, and Virginia Polytechnic Institute and State University. Actual performance may be better or worse than indicated in this chart **(*)**. (Table modified from 2002 Commercial Vegetable Production Recommendations, University of Maryland Cooperative Extension Bulletin 236)

Key: G = good, F = fair, P = poor, N = no control, I = insufficient data

Table 3. Potato herbicides for broadleaf weeds

	BROADLEAF WEEDS								
Herbicide	Carpet-weed	Cocklebur, Com.	Galinsoga, Hairy	Jimson-weed	Lambsqtr., Common	Morning-glory sp.	Pigweed sp.	Purslane, Common	Ragweed, Common
Preemergence or Preplant Incorporated:									

EPTC	G	P	N	P	F	F	G	G	P
Preemergence:									
linuron	G	P	G	P/F	G	P	G	G	F
s-metolachlor	F	N	G	N	P	N	G	F/G	N
metribuzin	G	F	G	F/G	G	F/P	F/G	F	G
pendimethalin	G	N	N	N	F/G	P	F/G	F/G	N
Postemergence:									
clethodim	N	N	N	N	N	N	N	N	N
rimsulfuron	-	F/G	G	F	F	F	G	F/G	P
metribuzin	G	-	G	G	G	P	G	G	G
sethoxydim	N	N	N	N	N	N	N	N	N

Herbicide performance is affected by weather, soil type, herbicide rate, weed pressure and other factors. These ratings indicate ONLY relative effectiveness in tests conducted by the University of Delaware, University of Maryland System, The Pennsylvania State University, Rutgers, The State University of New Jersey, and Virginia Polytechnic Institute and State University. Actual performance may be better or worse than indicated in this chart **(*)**. (Table modified from 1999 Commercial Vegetable Production Recommendations, University of Maryland Cooperative Extension Bulletin 236)

Key: G = good, F = fair, P = poor, N = no control, I = insufficient data

Vine Killing and Storage:
Vine Killing- Vine killers are not used in Maryland because the vines typically die as a natural termination of growth. This will occur based on variety and planting date. Vine collapse will occur within a two week period of maturity in the heat of July and August and usually do not interfere with harvest (31). For fresh market and processed potatoes, vines are mechanically killed, usually by mowing (31).

Storage- Vines of potatoes going into storage are killed 14 to 21 days before harvest. Tubers are maintained at a temperature of 50º to 60ºF for the first 2 to 3 weeks, to promote healing of cuts and bruises. After this, the storage temperature for table stock or seed potatoes is lowered to 40ºF. If the potential for rot is high, the curing period is eliminated and a storage temperature of 45ºF is used until the crop is sold (6).

Sprout inhibitors are applied directly to tubers after cuts and bruises from harvesting have healed.

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