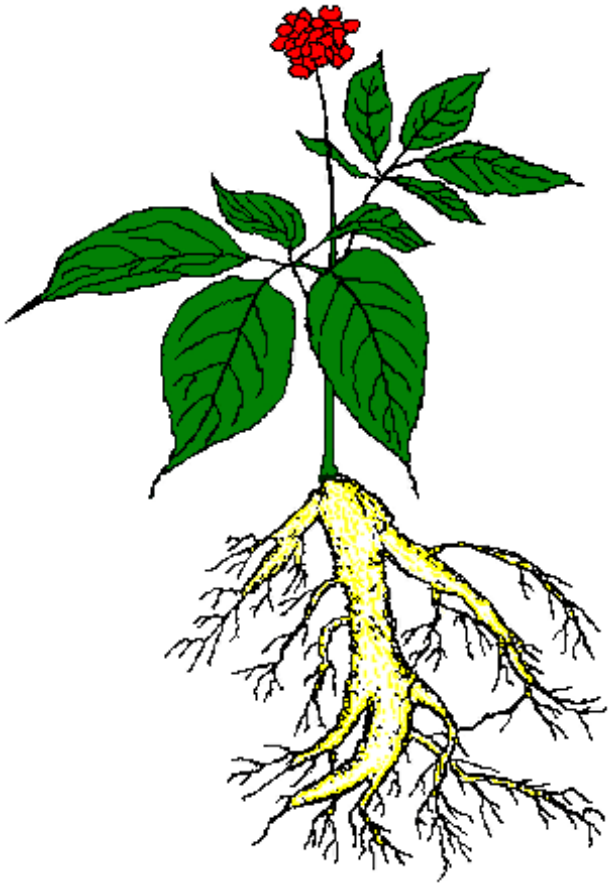
PEST MANAGEMENT IN THE FUTURE

A Strategic Plan for the Michigan and Wisconsin Ginseng Industry



Workshop Summary

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Michigan State University
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TOP PRIORITIES OF THE GINSENG INDUSTRY

RESEARCH:

- Develop management strategies for root rot diseases, including *Pythium*, *Rhizoctonia*, *Phytophthora*, *Cylindrocarpon,* and *Fusarium*.
  - Identify effective products.
  - Identify and develop effective methods for applying fungicides and biocontrol agents to the root zone. Determine whether drip applications are effective and efficient.
  - Test fumigants and methods of application.
- Develop management strategies for foliar blights, including Botrytis and Alternaria.
  - Identify effective products.
  - Identify environmental conditions favorable for disease development and develop weather monitoring programs and disease forecasting systems for growers.
- Determine the effect of mulching on plant pathogens, and identify materials that suppress pathogens.
- Identify pathogens that may be seed-borne and identify effective seed treatments.
- Determine whether cover crops can reduce or suppress pest pressure.
- Identify new active ingredients effective against grubs.
- Identify new active ingredients/formulations, application methods for slug control.
- Identify an effective postemergence broad spectrum herbicide that is safe on ginseng.
- Conduct a comprehensive survey of insects, pathogens, weeds, and determine which are economically important.
- Determine which pests or combination of pests are the primary contributors to overall yield decline.
- Refine the optimal nutrient management program, including application methods and impact on disease susceptibility.

REGULATORY:

- Broad spectrum fungicides (i.e., mancozeb [Dithane] and chlorothalonil [Bravo]), are needed for use in an alternation program with strobilurin fungicides.
- Maintain availability of the herbicide DCPA (Dacthal) and the insecticide diazinon for ginseng growers until comparable replacement products are identified and registered.
- When an effective and safe replacement is found for the herbicide DCPA (Dacthal) and the insecticide diazinon, speed registration.
- Utilize products labeled in the same crop grouping as ginseng to establish tolerance levels and speed registration.
- Partner with IR-4 to speed registration of chlorothalonil (Bravo), cymoxanil (Curzate), fludioxonil (Scholar), flutolanil (Moncut), dimethomorph (Acrobat), captan (Captan), and the biopesticide polyoxin D zinc salt (Endorse) for food use.
- Highlight the import laws and support enforcement, free trade, and an equal playing field with trade partners.
- Develop improved relations with the plant protection industry to facilitate needed information and product availability.
- Utilize a non-food use registration whenever possible to speed availability of needed products to the industry.

EDUCATIONAL:

- Develop fact sheets needed to identify insect pests, and the resulting crop damage, describe the life stages of the pest, and provide control measures.
- As new pest management products become available, information is needed regarding their activity and optimum use pattern.
- Develop information and grower education programs regarding disease symptoms and diagnosis.
- Provide plant nutrient education and management programs associated with new laws/regulations.
- Develop educational workshops that highlight effective management programs and establish optimal application techniques.

BACKGROUND

"Panax" is a Greek word that means "panakeia" or all-healing, and refers to the reputed medicinal value of ginseng which has been used extensively in oriental countries as a traditional medicine (Anonymous, 2000). In addition to having aphrodisiac properties, ginseng is considered to have curative activity for a number of human ailments, including short-term memory loss. The Food and Drug Administration classifies ginseng as a "generally recognized safe food" (Harrison et al., 2000). The root may be sold whole and intact, or as crystals, extract, or powder capsules. In some countries, the ginseng root is used in a variety of products, including toothpaste, soft drinks, tea, candy, chewing gum, and cigarettes. In the U.S., ginseng and ginseng products may be found in Asian food and health food stores.

American ginseng (*Panax quinquefolium* L.) is a perennial herb native to parts of the United States and Canada. Ginseng roots from native forests are most desirable and valuable. Woods-grown ginseng takes from 6 to 10 years to mature, at which time the roots are harvested. The limited supply of this type of ginseng and increasing demand led to cultivation in shaded "gardens" which began in the 1800s. Cultivated ginseng is grown in raised mulched beds under shaded conditions provided by wood lath or black polypropylene. Many ginseng gardens are small and typically less than one acre. Cultivated (artificial shade-grown) ginseng matures in 3 to 4 years with a production cost of $26,000/acre (Brun, 1999).

In Wisconsin, most growers harvest ginseng the third or fourth year after planting from seed (Harrison et al., 2000). In Michigan, woods-grown ginseng may be harvested as a more mature crop (i.e., 7 years or more). The roots are mechanically dug in the fall and vigorously washed to remove surface soil. It is important to handle the roots carefully to keep the branching forks intact and maintain the natural color and circular markings. Ginseng roots are dried on wire-netting shelves in a heated, well-ventilated room (Harrison et al., 2000). Since overheating destroys color and texture, the roots are dried at a temperature between 60°F and 80°F for the first few days, and then the temperature is gradually increased to about 90°F for three to six weeks. The drying roots are turned frequently. The roots are stored in a dry, well-ventilated, rodent-proof container just above freezing.

In mid-May to early June, growers begin applying products for pest control. Ginseng growers apply fungicides every 5 to 10 days until the middle of September. Since sprays (insect, disease, foliar fertilizers) may be applied separately, growers typically make more than one pass through a garden each week to apply the needed products. Most growers will have a labor crew remove the weeds in July. The size of the weed crew is dependent on the amount of acreage that needs to be weeded and the severity of infestation. Weed crews work in the gardens for two to three days. Seed harvest also requires a labor force. The seed harvest crews are generally the same personnel as the weeding crews. Finally, harvest requires additional labor. Harvest begins as early as September and may continue into November. Although harvesting is accomplished mechanically through the use of a modified potato digger, personnel are needed to retrieve roots that have been missed or dropped.

More than 90% of the cultivated ginseng grown in the U.S. is grown in Wisconsin (Drilias, 2002). Wisconsin's 400 growers cultivate 2,100 acres of ginseng, producing 500 to 1,700 lb/acre which represents 10% of the world's supply of ginseng root. At an approximate average of $20/lb, ginseng is a high value crop for Wisconsin, totaling approximately $50 to $75 million annually. While production is concentrated in the north-central part of the state (Marathon County), 37 other Wisconsin counties also have acreage devoted to ginseng cultivation. Woods-grown ginseng is a relatively new crop for Michigan, with the first seedlings

(Wisconsin transplants) being planted in 1995. Most of the ginseng production is located in Michigan's Upper Peninsula (Houghton County). Michigan has approximately 135 acres of woods-grown ginseng at various stages of maturity and 15 acres of cultivated ginseng. Woods-grown ginseng has a higher market value (up to 10 times) than that of cultivated ginseng. Based on current prices, this represents a Michigan inventory of over $50 million. Canada is also a significant producer of ginseng with approximately 8,000 acres grown in Alberta, British Columbia, and Ontario (Anonymous, 2000). Several states including West Virginia (Scott et al., 1995), North Carolina (Davis, 1997), New York (Friedlander, 1997), Washington (Brun, 1999), and Oregon have small but thriving ginseng industries.

Ginseng is established in early fall with seed that is planted into 5' wide raised beds that are 9" to 12" high. The following spring, woven panels providing 80% shade are suspended via 8-10 ft. posts in cultivated gardens to mimic wood-lot conditions. The micro-environment created through this culture, including reduced air movement, increased relative humidity, and increased duration of leaf wetness, is highly conducive to disease. Foliar blights caused by *Alternaria panax* and *Botrytis cinerea* are a primary problem for ginseng growers in Wisconsin (Parke and Shotwell, 1989) and Michigan (Hausbeck, 2003). When left uncontrolled, diseases can cause premature defoliation that affects plant growth and survival, resulting in small, poor quality roots with reduced market value. Premature defoliation as a result of foliar disease predisposes the root to soil-borne pathogens.

Alternaria panax is the most common pathogen of ginseng throughout the world (Li and Utkhede, 1993). It can attack shoots, leaves, and stems on plant of all ages. Senescing tissue and nutrient deficient plants are especially susceptible to infection by *A. panax*. The leaf blight includes lesions with yellow-green haloes, dark brown margins and pale brown centers. Established lesions may have a "shot-hole" appearance after the tissue in the center disintegrates. Stems can also become blighted and collapse. The potential for repeated widespread and devastating epidemics is great because *A. panax* produces large numbers of conidia (spores) on the surface of diseased leaves and stems. When weather is favorable (humid and wet), blight symptoms and reproduction of the fungus can occur in 5 to 7 days (Uchida, 2003). Outbreaks of *A. panax* in one season greatly increase the potential for epidemics in subsequent seasons, since the fungus overwinters in the infested plant debris. In the spring, conidia (spores) that overwintered can spread to the newly emerging healthy plants via rain or splashing water and begin the disease cycle for the new growing season. Conidia (spores) can travel via air currents, resulting in spread of *A. panax* from a diseased garden to nearby healthy gardens. Workers may also contribute to the spread of this fungus via contact with clothing and equipment (Uchida, 2003).

If Alternaria leaf and stem blight is not controlled, it can reach epidemic proportions within a month after the plants have emerged in the spring, destroying all of the foliage. This loss of foliage retards root growth in maturing crops, resulting in reduced root yields at harvest. Also, defoliation of young plants makes them more susceptible to winter kill. Repeated outbreaks in subsequent years can reduce yields further. The loss of yield reported by Wisconsin growers when the disease is uncontrolled range from 50 to 100%, with the majority of those surveyed reporting losses of 75 to 100% (Drilias, 2002). In addition, Alternaria leaf and stem blight can damage or destroy the seed crop normally harvested from 3-year-old ginseng gardens. In other ginseng-growing regions including Alberta (Chang et al., 1997; Chang et al., 1998), West Virginia (Scott et al., 1995), and North Carolina (Davis, 1997), Alternaria leaf and stem blight is recognized as the most devastating disease. Recently, *A. panax* was reported as a pathogen on ginseng in Oregon and Washington (Putnam and DuToit, 2002).

The fungicide iprodione (Rovral) was once very effective in controlling Alternaria leaf and stem blight in ginseng. However, Rovral failed to control Alternaria blight in mid-season in 1987 throughout Wisconsin. Laboratory tests confirmed the existence of an Alternaria population, which had become resistant to iprodione, the active ingredient in Rovral. Consequently, a severe epidemic of stem blight eliminated many gardens and significantly reduced the yields of most gardens. The copper hydroxide fungicide Kocide was made available in 1988 to be mixed with Rovral for control of Alternaria leaf blight in harvestable gardens where use of mancozeb (Dithane) was prohibited. Rovral/Kocide does not provide adequate disease control throughout the season, and should not be used prior to the harvest year, as it will allow a build-up of inoculum. When high inoculum levels are present at the time of plant emergence the following spring, the potential for an epidemic is greatly increased, because it is difficult to protect ginseng stems as they emerge through the infested mulch. Furthermore, the Rovral/Kocide combination appears to reduce the seed yield of treated plants.

Azoxystrobin (Quadris) and pyraclostrobin (Cabrio) are labeled for control of *Alternaria* and must be used in alternation with protectant fungicides (i.e., Dithane, Bravo) to delay the development of pathogen resistance. Mancozeb (Dithane) and chlorothalonil (Bravo) are critical fungicides for control of *Alternaria* and must be applied frequently over the course of the season to maintain adequate protection. These products have been available to ginseng growers through yearly Specific Exemptions to Section 18 of FIFRA or through a state-issued crisis exemption.

Botrytis cinerea is extremely common and can grow and survive on virtually any dead plant material found in a ginseng garden (Brammal and Fisher, 1993). Also called gray mold, this fungus is the same pathogen that causes crop loss on greenhouse bedding plants and cut flowers (Hausbeck and Moorman, 1996). Traditionally, ginseng growers considered *B. cinerea* a pathogen of flowers and fruits only, resulting in reduced seed yields. Infection of the flowers and fruit leads to discoloration, followed by abortion of these plant parts or infection of the developing seed. Without fungicides to protect against Botrytis blight, growers could lose up to 80-100% of their crop, especially if seedling gardens are affected.

In recent years, ginseng growers in Michigan and Wisconsin have reported an increased occurrence of leaf blight caused by *B. cinerea* (Drilias, 2002; M. Peever, Research Director, Ginseng Board of Wisconsin, personal communication). Botrytis leaf blight is the most common foliar disease affecting ginseng in Washington where the cool, cloudy weather, and frequent rainy periods are ideal conditions for pathogen development and spread (Brun, 1999). Typical symptoms include water-soaked, tan lesions that often have concentric rings, giving them the appearance of a bull's eye. Lesions often start at the leaf tips and proceed back along the leaf mid-rib. *Botrytis cinerea* can infect stems late in the growing season and may form small black bodies (sclerotia) on affected tissues that allow the fungus to overwinter. During periods of high humidity, the fungus produces high numbers of small, single-celled, colorless conidia (spores) on diseased or dead plant tissue. Conidia (spores) are released and disseminated when infected leaves or fruit clusters are disturbed by air currents or human activities. Field observations also suggest that the fungus can grow from leaf to leaf in densely planted gardens when diseased and healthy leaves come into contact. Withered flower petals or senescent leaf tissue that overlap healthy leaves can serve as the extra food source needed for *B. cinerea* to successfully infect intact, healthy plant tissue.

There are few modes of action or fungicide classes available for control of *B. cinerea*. Resistance of *B. cinerea* to fungicides severely limits chemical control options. Resistance to benomyl and cross-resistance to other benzimidazole fungicides in *Botrytis* populations are now common, while multiple resistance to both benzimidazole and dicarboximide fungicides is not

unusual. Rovral is a dicarboximide fungicide.

Resistant and sensitive strains of *B. cinerea* are often similar in fitness. Vali (1991) found that dicarboximide-resistant and -sensitive strains of *Botrytis* differ only slightly in fitness. Therefore, the resistant portion of the population does not decline significantly when the fungicide is no longer used. It was reported that a *Botrytis* population in a greenhouse where benzimidazole use ceased in the 1970s still exhibited resistance 12 years later. Alternating fungicides is ineffective in suppressing resistant *Botrytis* populations because the population does not decline significantly during the relatively short period of time that the fungicide is not present. Mixing chemicals with different modes of action is also ineffective in managing resistance if the chemical to which the fungus is resistant is included in the mixture. Although most of the fungicide-sensitive conidia will be killed with such a mixture, the remaining fungicide-resistant conidia will not be completely controlled. Surviving resistant conidia will germinate, infect, and give rise to many more conidia resistant to the fungicide. Thus, there is no management benefit from using the fungicide once resistance is present.

Fenhexamid (Elevate) is approved for non-food use in ginseng for *Botrytis* control, but it cannot be used in the harvest year when quality is especially critical. Also, this product has not been locally available through pesticide distributors. A maximum of four applications may be made. Azoxystrobin (Quadris) and pyraclostrobin (Cabrio) are labeled for control of *Alternaria* only but offer limited *Botrytis* suppression. These products must be used judiciously and in alternation with protectant fungicides to delay the development of pathogen resistance.

Chlorothalonil (Bravo Weather Stik 6SC) is available as Daconil for use on ornamentals in the greenhouse where *Botrytis cinerea* is a persistent problem. Historically, chlorothalonil (Bravo) has not been available to ginseng growers. However, the unusually wet and cold spring and summer necessitated a crisis exemption for Michigan and Wisconsin. A Specific Exemption to Section 18 of FIFRA is pending. Michigan State University has conducted numerous trials over several years and demonstrated that chlorothalonil is a superior product for *B. cinerea* control. The protectant fungicide mancozeb (Dithane) does not offer the needed level of *Botrytis* control when environmental conditions favor disease. Chlorothalonil also has excellent activity against *Alternaria*.

Powdery mildew was a common problem in Wisconsin ginseng gardens during the 2004 growing season. Symptoms of powdery mildew, caused by the fungus *Erysiphe* sp., include powdery, white, superficial spots of conidia on the upper surface of leaves. Infected tissue turns reddish purple, and infected leaves turn yellow and may drop. Severe disease early in the season may reduce seed production, root fresh weight and winter hardiness (Chang, et al., 1999). Powdery mildew pathogens overwinter on infested plant debris. Conidia are produced throughout the summer when the environment favors fungal growth. Incidence is likely more severe during cool, cloudy weather (Howard et al., 1994).

Root rots are a primary concern of ginseng growers and include *Rhizoctonia solani*, *Fusarium* spp., *Pythium* spp., and *Phytophthora cactorum* (Chang et al., 1997 and 1998). *Cylindrocarpon destructans* also plays a significant role in declining gardens and replant problems and has been isolated from many Wisconsin root samples (Hausbeck, unpublished data).

Fusarium spp., *Pythium* spp., *P. cactorum*, and *R. solani* are soil-borne fungi that cause pre-emergence damping-off and post-emergence seedling root rot, especially in 1- and 2-year-old ginseng plants (Chang et al., 1997 and 1998). *Rhizoctonia solani* causes damping-off, and crown and bud rot. Once the crown becomes infected, winter kill of the plant is likely, preventing emergence in the spring. Damping-off fungi can occur early in production by causing

a seed rot and attacking seedlings before they emerge from the soil. Post-emergence damping-off is more readily recognized because the damping-off fungus attacks at the soil line after the seedling emerges from the soil. Wilting of the seedling occurs when stems are infected, which causes water-soaking, and constriction. Seedlings collapse at the point of constriction. *Fusarium* spp. and *Pythium* spp. can produce spores on ginseng debris. Some pathogens use the straw mulch to spread from plant to plant, and some spread through the soil as saprophytes until they contact the ginseng plants (Howard et al., 1994).

Phytophthora cactorum is a serious threat to growing ginseng in Michigan and Wisconsin. This pathogen is favored during wet weather and can destroy entire ginseng plantings within a few weeks. Initial symptoms include a bronzing and wilting of the foliage with infected roots becoming discolored and spongy and eventually disintegrating. While *P. cactorum* is a soil-borne pathogen, there is a foliar blight phase that results in severe damage to the leaves.

This pathogen is a common, widely distributed, soilborne fungus with a very wide host range, attacking about 200 different species of plants in over 80 genera. *Phytophthora cactorum* can be found in agricultural and non-agricultural soils including those near apple orchards and forests. Since ginseng is typically established in wood lots or on recently cleared land, *P. cactorum* may be endemic in some instances. The pathogen overwinters as mycelium in diseased roots or may survive for several years as thick-walled oospores or chlamydospores in the soil. These thick-walled structures resist periods of unfavorable environment such as drought or freezing temperatures and are relatively resistant to chemical treatment. The fungus can also form sporangia and zoospores that may be splashed to foliage causing blight. The ability to produce large numbers of spores (primarily zoospores) allow the *Phytophthora* fungus to build up to high levels rapidly. This pathogen may also be seed-borne.

Metalaxyl or mefenoxam (Ridomil 2E or Ridomil Gold) applied as a pre-emergent fungicide has been relied on by the ginseng industry for many years to control Phytophthora leaf and root rot. Other fungicides such as copper and Dithane are inadequate against this oomycete pathogen when disease pressure is moderate to severe. Oomycete pathogens require a fungicide that specifically targets them. A protectant such as mancozeb will provide limited suppression of the foliar phase of disease, but under moderate disease pressure will not provide commercial control. *Phytophthora* spp., in general, affect a number of crops and in those situations, fungicides specific for the oomycete pathogens have been needed to avert epidemics.

In 2003, Michigan State University received diseased ginseng roots from growers in Michigan and Wisconsin. Over 100 *P. cactorum* isolates were obtained from diseased ginseng plants. These isolates have been screened for resistance to the fungicide Ridomil Gold and 85 (76%) of them have been found to be fully resistant to Ridomil Gold. This coincides with the observations of growers in both states who believe that they have had control failure the last several years resulting in losses of catastrophic proportions. Resistance to Ridomil Gold is unlikely to lessen, and we anticipate continued resistance to this fungicide.

The soilborne fungus, *Verticillium dahliae*, causes plant wilting and death, and is a sporadic problem. This fungus can infect other crops besides ginseng, including eggplant, tomato and potato (Sherf and MacNab, 1986). It generally affects older ginseng plants. Ginseng leaves wilt and droop parallel to the stem, and the plant eventually dies. Roots remain firm, but the vascular tissue is discolored yellow. Symptoms often appear later in the season when plants become senescent. *Verticillium dahliae* overwinters as microsclerotia in infected plant debris. The fungus penetrates into the vascular tissue of ginseng at the sites of leaf scars, and can likely penetrate the roots directly. It grows and spreads through the xylem vessels blocking movement

of water in the plant, and forms microsclerotia in dead tissues. Disease development in ginseng is favored by temperatures below 20°C. The fungus can be spread by infested soil, farm machinery and irrigation water. *Verticillium* can persist in the soil as microsclerotia (Howard et al., 1994). Currently, there are no registered fungicides to control this pathogen.

The fungus, *Cylindrocarpon destructans*, causes disappearing root rot, a disease that affects plants of all ages. The disease affects all underground plant parts causing near total destruction. *Cylindrocarpon destructans* causes infections near the root tip, progressing upwards until most of the root is infected. This pathogen can also cause a crown rot and root "stubbing." *Cylindrocarpon destructans* is common in soils of coniferous woodlands, and occurs in a wide range of soil types. Initial infections appear as small, gold to brown areas on the root surface which enlarge rapidly and deepen into a reddish-brown, spongy rot. The root exterior becomes dark brown at infection sites. Lateral rootlets may be affected, producing a distorted taproot, and the infection can advance into the crown and stem. Only fragments of the root tissues remain in advanced stages of the disease. Diseased plants may fail to emerge. Foliar symptoms include wilting that is often one-sided. Foliage can turn red to brown after repeated wilting, with aerial portions of the plant often dying. The disease appears in ginseng gardens as concentrically expanding patches of wilting or dead plants. Conidia form on the surface of rotted roots and can be spread on clothing or machinery or in infested soil. Dense plant populations may allow the pathogen to spread through direct contact of roots. *Cylindrocarpon* is believed to overwinter as thick-walled chlamydospores in soil or on infested plant residue (Howard et al., 1994). Despite the devastating losses caused by this pathogen, registered fungicides are not available.

Sclerotinia sclerotiorum, causes a stem and root rot of ginseng. This fungus has a wide host range. Symptoms of Sclerotinia white rot include foliage that wilts, and becomes discolored and desiccated. Roots appear soft and watery. Black sclerotia form on infected plant parts, and these can survive for ≥5 years in soil and ginseng debris. The fungus thrives in moist, cool conditions. Sclerotia within 2-5 cm of the soil surface produce apothecia (which contain ascospores) after several weeks at about 4°C. The ascospores are released into the air. The spores need 48-72 hours of wetness to infect, and disease can develop rapidly at 20-25°C. Mycelium can spread between plant parts that are in contact (Howard, et al., 1994). There are no fungicides registered to limit this pathogen.

Stromatinia black rot is caused by the fungus, *Stromatina panacis*, which also has been known to infect false solomon's seal, a woodland plant. Growth of *Stromatinia* is favored by cool moist conditions and most infections occur in the spring and fall. There are no leaf symptoms, but infected plants fail to emerge in the spring. Roots are intact, but are black and may have bumps (sclerotia) on the surface. The inside tissue is white, watery and spongy, and may have sclerotia present (Anonymous, 2003). Little detail is known about this disease and the fungus that causes it. Another species of this genus, *S. gladioli*, causes corm rot of gladiolus, and information about this disease is applicable to ginseng. Stromatinia black rot is found during periods of cool, wet weather and produces a dry rot of all below-ground plant parts (Pfleger and Gould, 2002). Rotting of the leaf bases often results in premature yellowing and death of the tops (Pataky, 1983). Often plants are infected in groups as the fungus spreads from the original infected plant. Diseased roots characteristically have many small lesions ranging in size from pinpoints to about ½ inch in diameter. The lesions are minute and reddish brown at first, usually developing on the side and lower half of the root, but frequently appear on the upper half as well. The line separating the healthy and diseased tissue is rather sharp. As the lesions enlarge, the centers become sunken and usually turn black with definite, slightly raised margins. The lesions often merge into large irregular areas. Very small black sclerotia form in infected tissue. When

infected roots are cut vertically in half, blackened vascular strands can be seen that extend from the core to the surface of the root. The decayed tissue is corky in texture and mummification of the roots often occurs in storage. There is little known regarding the activity of fungicides on this pathogen.

Very little is known about ginseng disease caused by *Septonema* sp. This fungus has been isolated from diseased buds, roots, seeds, and seedlings of ginseng grown in Michigan and Wisconsin. Infected roots have a brown to tan superficial discoloration. This fungus is not reported as a pathogen on other crops.

Fusarium root rot (*Fusarium* spp.) results in disease of the stem, crown, roots, and foliage. Vascular discoloration is a common symptom of infection, and is typically preceded by the leaves wilting. *Fusarium* has been isolated from untreated ginseng seed and can cause damping off of emerging seedlings. In general, fungicides that are active against *Fusarium* spp. have not been identified.

Several insects are known pests of ginseng. Cutworms are the larvae of several species of night-flying moths in the family Noctuidae. Larvae can be recognized by their habit of curling into a "C" when they are disturbed. Larvae feed in the evenings on stems of young plants, girdling and chewing the tops as they emerge. Some species overwinter as eggs, whereas some adults fly in from the south yearly. Most damage in ginseng occurs on the outer edges of the garden (Schooley, 2000). Typical cutworm damage includes a wilted young 1- or 2-year old plant that has fallen over, and separated from the root (Anonymous, 2003). The variegated cutworm is a major pest of concern for ginseng growers, especially in the first year of production.

Four-lined plant bugs cause economic damage on ginseng seedlings, but feed on plants of all ages. These insects are approximately 7 mm in length, and have four black stripes that extend the length of the wings, contrasted with a bright green to yellow color. Nymphs do not have wings, and have brightly colored markings of red to yellow. Sharp mouth parts pierce the ginseng leaf and suck the leaf contents leaving the upper and lower epidermis. Fresh feeding spots (1-2 mm diameter) are initially dark colored, but quickly become white or tan and papery. Spots can coalesce if feeding is intense, which can prevent photosynthesis. Eggs overwinter, and nymphs appear in late May. Adults are very mobile and most active in ginseng in late June and July, depending on temperature (Schooley, 2000).

The leaf roller is the larva of a small moth (*Archips purpurana*), usually less than an inch in length. Adults lay eggs on ginseng leaves, and the larva folds a leaf around itself, by partially chewing the petiole to allow the leaf to droop and become easier to manipulate. One larva occupies each rolled leaf. The larva feed on ginseng during the day and seek shelter in the rolled leaf at night (Schooley, 2000).

Wireworms are yellowish-brown, shiny, slender, hard-bodied worms up to 1 inch long. Wireworms bore into seeds and seedlings, destroying them and, in heavy infestations, may feed on established plants Anonymous, 2003).

Aphids are small, soft-bodied insects with piercing-sucking mouthparts. They cause damage by piercing the foliage and sucking the plant sap. Feeding can twist and distort new growth. Aphids can also transmit viruses in many different crops (Howard et al., 1994).

Cultivated ginseng is highly susceptible to slug damage in the spring when the weather is cool and damp. Slugs have rasping mouthparts, and ragged holes in the leaves and mucus trails are characteristic symptoms of slug feeding. A very small amount of slug feeding on developing leaves probably has very little effect on eventual root yield (Brun, 1999). Slugs can shelter in tall grass, under litter or mulch, or can burrow into the soil. Most slug feeding occurs at night or

on cloudy days, when it is cool and humid. During dry conditions, they can protect their bodies with mucus secretions. Overwintered slug eggs hatch early in the spring. Slugs are hermaphroditic (have both male and female organs), male organs usually develop first, then they mate. After the male organs degenerate, the slugs become female, and lay 30-150 eggs in the fall (Howard et al., 1994).

The northern root-knot nematode causes mature ginseng roots to be deformed, short, and branched, with secondary roots that are abnormally branched and hairy. A high density of nematodes in soil causes areas of missing or stunted plants in a ginseng garden. Leaves usually appear healthy, but they may be smaller and light colored, or may have a reddish tinge on the back of the leaves. Older leaves can turn yellow and dry prematurely. Infected plants senesce early. Small swellings and branches become visible on the lateral roots a few weeks after planting, and tap root development is delayed. Marketable yields and quality are reduced. Northern root-knot nematode attacks many different vegetable crops. The second stage juveniles are attracted by root secretions and migrate to roots and penetrate the root tips soon after seed germination and root elongation. They induce formation of giant cells (knots) which they feed on. Females lay eggs in brown gelatinous masses (which appear the size of a small pin head to the naked eye) on the surface of the knots within a few weeks at soil temperatures around 20C. The second stage juveniles develop in about 2 weeks, and can reinfect new roots (Howard et al., 1994).

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OUTLINE OF PLAN

Following is a pest by pest analysis of the current role of pesticides registered for use in ginseng production with emphasis on those classified as organophosphates, carbamates, and B2 carcinogens. Other pest management tools (chemical, cultural and otherwise) that offer some control or are important in pest resistance management, but are not "stand alone" tools, are also discussed. In some instances, products that through preliminary research have been identified as effective, but are currently unavailable for use on ginseng, are discussed under the heading "pipeline pest management tools." Immediately following each pest analysis is a "to do" list for research, regulatory, and educational needs. Pests are presented in alphabetical order.

INSECT PESTS and other invertebrates

1. APHIDS (Family Aphididae)

Aphids infest the berries and leaves and feed via sucking. An occasional problem later in the season, especially when gardens are located near an alfalfa field.

Carbamate insecticides currently registered for aphids:

- None identified.

Other insecticides currently registered for aphids:

- Azadirachtin (Neemix 4.5): Efficacy – potentially fair to poor, feeding repellent. Not tested on ginseng. Classified as a biopesticide. Not used by growers.
- Imidacloprid (Admire, Provado): Efficacy – potentially good. Not tested on ginseng. Classified as an OP alternative.
- Pyrethrins/piperonyl butoxide (Pyrenone): Efficacy – potentially good. Not tested on ginseng. Only foliar insecticide used.
- Spinosad (SpinTor): Efficacy – unknown. Not tested on ginseng. Classified as a reduced-risk pesticide.

Other pest management aids for aphids:

- Site selection: Do not plant near an alfalfa field.
- Scout and spot-treat infested area.

Pipeline pest management tools for aphids:

- Pymetrozine (Fulfill): Efficacy – unknown. Not tested on ginseng. New product. Labeled for potato and other tuberous root and corm vegetables – sweet potato, true and bean yam, Jerusalem and Chinese artichoke, edible canna, chayote root, arracacha, arrowroot, bitter and sweet cassava, chufa, dasheen, ginger, leren, tanier, turmeric but not ginseng.
- Thiamethoxam (Actara, Platinum): Efficacy – unknown. Not tested on ginseng. Labeled for tuberous root and corm vegetables. (Same as pymetrozine.)

"To do" list for aphids:

Research needs:

- Conduct a survey to determine the species that affect ginseng.
- Test registered and unregistered products for efficacy and crop safety.

Regulatory needs:

- None identified.

Educational needs:

- Demonstration plots with commercial growers needed.

- Determine the population of aphids that can be tolerated without negatively impacting yield or quality.

2. CUTWORMS (Family Noctuidae) (Likely variegated cutworm, *Peridroma saucia*)

Cutworms are one of the top three insect problems affecting ginseng. Cutworms, the larvae of night-flying moths, feed on stems, girdling young plants and chewing ginseng tops. This insect is a particularly troubling pest in seedling beds.

Organophospate insecticides currently registered for cutworms:

- Diazinon (Diazinon G): Efficacy – good to excellent. Granular formulation is effective only against variegated cutworm. Used widely by growers.

Carbamate insecticides currently registered for cutworms:

- None identified.

Other insecticides currently registered for cutworms:

- Azadirachtin (Neemix 4.5): Efficacy – potentially poor. Not tested on ginseng. Classified as a biopesticide.
- Imidacloprid (Admire, Provado): Efficacy – potentially poor. Not tested on ginseng. Classified as an OP alternative.
- Spinosad (SpinTor): Efficacy – potentially good. Not tested on ginseng. Product is expensive. Classified as a reduced-risk pesticide.

Other pest management aids for cutworms:

- Choose an uninfested site (following a cereal crop is recommended).
- Till the site thoroughly.

Pipeline pest management tools for cutworms:

- Lambda-cyhalothrin (Warrior): Efficacy – unknown. Not tested on ginseng. Classified as an OP alternative.

"To do" list for cutworms:

Research needs:

- Determine which cutworm species are the primary pests.
- Test products that are registered and unregistered for efficacy and crop safety.

Regulatory needs:

- Retain the use of diazinon for ginseng production until cost effective and safe replacements are identified and registered.

Educational needs:

- Provide educational programs to help growers identify which cutworms are affecting their ginseng so that appropriate control measures are used.

3. FOUR-LINED PLANT BUGS (*Poecilocapsus lineatus*)

Four-lined plant bugs cause economic damage on ginseng seedlings. Sharp mouth parts pierce the ginseng leaf and suck the leaf contents leaving the upper and lower epidermis. Fresh feeding spots (1-2 mm diameter) are initially dark colored, but quickly become white or tan and papery. Spots can coalesce if feeding is significant, which can prevent photosynthesis. Not a significant problem in Wisconsin and Michigan. Possibly a problem associated with an alfalfa rotation.

Organophospate insecticides currently registered for four-lined plant bugs:

- None identified.

Carbamate insecticides currently registered for four-lined plant bugs:

- None identified.

Other insecticides currently registered for four-lined plant bugs:

- Azadirachtin (Neemix 4.5): Efficacy – unknown. Not tested on ginseng. Classified as a biopesticide. Acts as a feeding repellent.
- Imidacloprid (Admire, Provado): Efficacy – unknown. Not tested on ginseng. Classified as an OP alternative.
- Spinosad (SpinTor): Efficacy – unknown. Not tested on ginseng. Classified as a reduced-risk pesticide.

Other pest management aids for four-lined plant bugs:

- None identified.

Pipeline pest management tools for four-lined plant bugs:

- None identified.

"To do" list for four-lined plant bugs:

Research needs:

- Conduct efficacy studies to determine which products are effective and ensure crop safety.

Regulatory needs:

- None identified.

Educational needs:

- Train growers how to scout for this pest.
- Provide educational programs to help growers identify the four-lined plant bug so it can be determined whether this is a broadly distributed pest.

4. LEAF ROLLERS (*Archips purpurana*)

One of the top three insect problems in Michigan's production of ginseng in wood lots, although it is not a problem in Wisconsin. The larva folds a leaf around itself, by partially chewing the petiole to allow the leaf to droop and become easier to manipulate. The larva will feed on ginseng during the day and seek shelter in the rolled leaf at night.

Organophospate insecticides currently registered for leaf rollers:

- None identified.

Carbamate insecticides currently registered for leaf rollers:

- None identified.

Other insecticides currently registered for leaf rollers:

- Azadirachtin (Neemix 4.5): Efficacy – potentially poor. Not tested on ginseng. Classified as a biopesticide.
- Imidacloprid (Admire, Provado): Efficacy – potentially poor. Not tested on ginseng. Classified as an OP alternative.
- Spinosad (SpinTor): Efficacy – potentially good. Not tested on ginseng. Classified as a reduced-risk pesticide.

Other pest management aids for leaf rollers:

- Manually remove affected leaf.
- Scout and spot treat as needed.

Pipeline pest management tools for leaf rollers:

- None identified.

"To do" list for leaf rollers:

Research needs:

- Conduct a survey to determine which species are common problems.

Regulatory needs:

- None identified.

Educational needs:

- Help growers identify the species causing the infestation.
- Provide specific education on the use and efficacy of registered products.

5. MILLIPEDES (Class Diplopoda)

Commonly observed in ginseng gardens. Typically considered to be innocuous feeders of composting vegetation. Since higher populations are observed in areas where plants are suffering from root rot, growers sometimes associate their presence with problems such as root feeding.

Organophospate insecticides currently registered for millipedes:

- Diazinon (Diazinon G): Efficacy – unknown. Not tested on ginseng.

Carbamate insecticides currently registered for millipedes:

- None identified.

Other insecticides currently registered for millipedes:

- Azdirachtin (Neemix 4.5): Efficacy – potentially poor. Not tested on ginseng. Classified as a biopesticide.
- Imidacloprid (Admire, Provado): Efficacy – potentially poor. Not tested on ginseng. Classified as an OP alternative.
- Spinosad (SpinTor): Efficacy – potentially poor. Not tested on ginseng. Classified as a reduced-risk pesticide.

Other pest management aids for millipedes:

- None identified.

Pipeline pest management tools for millipedes:

- None identified.

"To do" list for millipedes:

Research needs:

- Determine if this is an important pest on ginseng.

Regulatory needs:

- None identified.

Educational needs:

- Describe the feeding pattern to growers to help them determine when conditions may allow millipedes to cause damage.

6. SLUGS (Order Anaspidea)

Considered to be one of the top insect problems. Ragged holes in the leaves and mucus trails are the characteristic symptoms of slug feeding. Most slug feeding occurs at night.

Organophospate insecticides currently registered for slugs:

- None identified.

Carbamate insecticides currently registered for slugs:

- None identified.

Other insecticides currently registered for slugs:

- Metaldehyde (Deadline bullets, Slugfest, different sizes): Efficacy – good. Widely

used by growers and applied monthly during the growing season.

Other pest management aids for slugs:

- Sawdust mulch, delay shading the garden until it is dry, till/sawdust surrounding area mulch. Eliminate shady, damp areas; clean cultivation and removal of sheltering sites along hedgerows/fences; do not plant in low, flat, wet or recently plowed ground that has been left idle for several years. Beer is an attractant and can be used to monitor populations (Brown, 2001).
- Diatomaceous earth is fossilized diatoms (which contain silica) that are ground into microscopic sharp particles that penetrate insect cuticles and slug epidermis causing dehydration and death, but are harmless to animals and humans. Needs to be reapplied after rain.
- Remove weeds around gardens to reduce favorable slug habitat.

Pipeline pest management tools for slugs:

- None identified.

"To do" list for slugs:

Research needs:

- Identify and test potentially effective products. In particular, explore those products that have a granular formulation.

Regulatory needs:

- Another form of metaldehyde (Trails End LG) is desired for more uniform dispersal and enhanced efficacy.
- Rapid registration of additional products that are shown to be effective and safe on ginseng.

Educational needs:

- None identified.

7. SPITTLE BUGS (Family: Cercopidae)

One of the top insect problems in Michigan ginseng production in wood lots, less of a problem in Wisconsin. Destroys the flower head and damages the seed.

Organophospate insecticides currently registered for spittle bugs:

- None identified.

Carbamate insecticides currently registered for spittle bugs:

- None identified.

Other insecticides currently registered for spittle bugs:

- Azadirachtin (Neemix 4.5): Efficacy – potentially fair to poor. Not tested on ginseng. Classified as a biopesticide.
- Imidacloprid (Admire, Provado): Efficacy – potentially good. Not tested on ginseng. Classified as an OP alternative.
- Pyrethrins/piperonyl butoxide (Pyrenone): Efficacy – potentially fair to poor. Not tested on ginseng.
- Spinosad (SpinTor): Efficacy – potentially good. Not tested on ginseng. Classified as a reduced-risk pesticide.

Other pest management aids for spittle bugs:

- Scouting coupled with spot treatment as needed.

Pipeline pest management tools for spittle bugs:

- None identified.

"To do" list for spittle bugs:

Research needs:

- Determine the economic impact of an infestation.
- Determine the population level that triggers a treatment.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

8. THRIPS (Order Thysanoptera)

Growers are uncertain as to whether this insect is a major problem for the industry. There was a discussion that included the potential for thrips in the flowers and a possibility of thrips feeding injury providing an entry for Botrytis infection.

Organophospate insecticides currently registered for thrips:

- None identified.

Carbamate insecticides currently registered for thrips:

- None identified.

Other insecticides currently registered for thrips:

- Azadirachtin (Neemix 4.5): Efficacy – unknown. Classified as a biopesticide.
- Imidacloprid (Admire, Provado): Efficacy – unknown. Classified as an OP alternative.

Other pest management aids for thrips:

- None identified.

Pipeline pest management tools for thrips:

- None identified.

"To do" list for thrips:

Research needs:

- Determine the potential for thrips to be a significant problem or vector of disease.
- Conduct a survey to determine which thrips species are a potential threat to ginseng.

Regulatory needs:

- None identified.

Educational needs:

- Help growers learn where to look for thrips and identify them.

9. TREEHOPPERS (Family Membracidae)

A problem among seedlings established in wood lots. Infestation by this pest causes the seedling to collapse. Although this is a problem in Michigan, it is not an issue for Wisconsin growers.

Organophospate insecticides currently registered for treehoppers:

- None identified.

Carbamate insecticides currently registered for treehoppers:

- None identified.

Other insecticides currently registered for treehoppers:

- Azadirachtin (Neemix 4.5): Efficacy – potentially poor. Not tested on ginseng. Classified as a biopesticide.

- Imidacloprid (Admire, Provado): Efficacy – potentially good. Not tested on ginseng. Classified as an OP alternative.
- Pyrethrins/piperonyl butoxide (Pyrenone): Efficacy – potentially good. Not tested on ginseng.
- Spinosad (SpinTor): Efficacy – potentially good. Not tested on ginseng. Classified as a biopesticide.

Other pest management aids for treehoppers:

- None identified.

Pipeline pest management tools for treehoppers:

- None identified.

"To do" list for treehoppers:

Research needs:

- Sample and survey gardens established in wood lots to determine the extent of the problem.
- Determine the genus and species of this pest.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

10. WHITE GRUBS (Family Scarabidae)

Grubs feed on the root, resulting in a "hollowing out" of the root. They have a long life cycle, and are a common problem in Michigan and Wisconsin.

Organophospate insecticides currently registered for white grubs:

- Diazinon (Diazinon G): Efficacy – good. Widely used by growers.

Carbamate insecticides currently registered for white grubs:

- None identified.

Other insecticides currently registered for white grubs:

- Azadirachtin (Neemix 4.5): Efficacy – potentially poor. Not tested on ginseng. Classified as a biopesticide.
- Imidacloprid (Admire, Provado): Efficacy – potentially good. Not tested on ginseng. A potential for use on seedlings. Its formulation would make it difficult to use on established gardens and reach the insect pest because of the mulch layer. Classified as an OP alternative.
- Pyrethrins/piperonyl butoxide (Pyrenone): Efficacy – potentially poor. Not tested on ginseng.
- Spinosad (SpinTor): Efficacy – potentially poor. Not tested on ginseng. Classified as a reduced-risk pesticide.

Other pest management aids for white grubs:

- None identified.

Pipeline pest management tools for white grubs:

- None identified.

"To do" list for white grubs:

Research needs:

- Determine which white grub species are the primary pests.
- Determine whether trap crops or rotational practices can reduce white grub pressure and damage.

- Test products that are registered and new, unregistered products for efficacy, including entomopathic nematodes.

Regulatory needs:

- Retain the use of diazinon for ginseng production until cost effective and safe replacements are identified and registered.

Educational needs:

- As new cultural and chemical tools are identified, instruct growers on their uses.

11. WIREWORMS (Family Elateridae)

Wireworms feed on roots and ungerminated or newly germinated seeds, especially of cereal crops.

B2 carcinogenic insecticides currently registered for wireworms:

- 1,3-Dichloropropene (Telone II): Efficacy – potentially good. Not tested on ginseng. Classified as a partial methyl bromide alternative. Expensive.
- 1,3-Dichloropropene/chloropicrin (Telone C-17, C-35): Efficacy – potentially good. Not tested on ginseng. Classified as a partial methyl bromide alternative by IR-4. Expensive.

Organophospate insecticides currently registered for wireworms:

- None identified.

Carbamate insecticides currently registered for wireworms:

- None identified.

Other insecticides currently registered for wireworms:

- Azadirachtin (Neemix 4.5): Efficacy – potentially poor. Not tested on ginseng. Classified as a biopesticide.
- Imidacloprid (Admire, Provado): Efficacy – potentially fair. Not tested on ginseng. Classified as an OP alternative. A potential for use on seedlings. Its current formulation would make it difficult to use on established gardens and reach the pest through the mulch layer.
- Pyrethrins/piperonyl butoxide (Pyrenone): Efficacy – potentially poor. Not tested on ginseng.
- Spinosad (SpinTor): Efficacy – potentially poor. Not tested on ginseng. Classified as a reduced-risk pesticide.

Other pest management aids for wireworms:

- Cover crops may be helpful, although cereal crops should be avoided since they are preferred for feeding.
- Scouting (use corn or oats to bait).
- Choose sites that have not recently hosted cereal crops.

Pipeline pest management tools for wireworms:

- None identified.

"To do" list for wireworms:

Research needs:

- Survey and sample ginseng gardens to assess the level of infestation.
- Determine the level of damage caused by this pest.
- Determine whether fumigation is cost effective.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

FUNGAL PATHOGENS

1. ALTERNARIA BLIGHT (*Alternaria panax*)

Above-ground symptoms include lesions with yellow-green halos, dark brown margins and pale brown centers. Infected roots turn dark brown, flatten, and often completely die. White mycelium may colonize the basal plate in advanced stages of infection. A common, yearly problem. This *Alternaria* species is especially aggressive and can cause total plant death within three weeks if left untreated. Weather conditions drive the severity of the disease. Frequent rainfall and high humidity are especially favorable for Alternaria blight, and necessitate frequent fungicide applications.

B2 carcinogenic fungicides currently registered for Alternaria blight:

- Iprodione (Iprodione, Rovral): Efficacy – good to poor. Documented pathogen resistance makes this a risky product to use. When used, it should be alternated with products that have a different mode of action.

Other fungicides currently registered for Alternaria blight:

- Azoxystrobin (Quadris, Amistar): Efficacy – good to excellent. Classified as a reduced-risk fungicide. Widely used. Development of pathogen resistance is a significant concern. To delay the development of resistance, this fungicide needs to be used in alternation with a fungicide with a different mode of action.
- Copper hydroxide (Champ, Kocide, Nu-Cop): Efficacy – fair to poor. May be tank mixed with other fungicides or used alone. May help limit disease, but will be overwhelmed when disease pressure is significant. Frequent use of copper is a significant concern of ginseng growers because of potential phytotoxicity.
- Hydrogen dioxide (OxiDate): Efficacy – potentially poor. Not tested on ginseng. Classified as a biopesticide. Not used by growers.
- Neem oil (Trilogy): Efficacy – potentially poor. Not tested on ginseng. Classified as a biopesticide. Not used by growers.
- Pyraclostrobin (Cabrio WG): Efficacy – good to excellent. Widely used. Classified as a reduced-risk fungicide. Development of pathogen resistance is a significant concern. To delay the development of resistance, this fungicide needs to be used in alternation with a fungicide with a different mode of action.

Other pest management aids for Alternaria blight:

- Garden size is limited to enhance air flow and movement to reduce the environmental conditions that favor disease development.
- Monitor the environment and treat preventively when environmental conditions favor disease development.
- Rotate crops to avoid pathogen buildup.

Pipeline pest management tools for Alternaria blight:

- Chlorothalonil (Bravo): Efficacy – good to excellent. Classified as a B2 carcinogen. A Specific Exemption to Section 18 of FIFRA for use of chlorothalonil on *Botrytis* and *Alternaria* in Michigan and Wisconsin is pending for 2004. A crisis exemption was granted by the state departments in Michigan and Wisconsin to limit disease epidemics resulting from unusually wet weather. Although labeled specifically for *Botrytis*, it has a broad spectrum of control that includes *Alternaria*. It was widely used by growers in 2004 with very favorable results. Considered a priority in 2003 for registration through IR-4.

- Mancozeb (Dithane): Efficacy – good. Classified as a B2 carcinogen. Available through a Specific Exemption to Section 18 of FIFRA for use on *Alternaria* in Michigan and Wisconsin for 2004.

"To do" list for Alternaria blight:

Research needs:

- Polyoxin D zinc salt (Endorse): Classified as a biopesticide. Determine the efficacy against Alternaria and overall crop safety. Preliminary tests look promising for at least limited control, but further research is needed. Endorse has the potential to serve as a rotational product for the strobilurins.
- Develop a forecasting model to characterize the environmental conditions that favor disease progression, and time sprays accordingly.

Regulatory needs:

- Speed the registration of protectant products for use in alternation with the strobilurins. Broad spectrum products such as chlorothalonil (Bravo) and mancozeb (Dithane) are both needed as cornerstone products for foliar blight control. This is a top priority among ginseng growers.
- Boscalid (Endura): Classified as a reduced-risk fungicide. Expand studies regarding its efficacy and overall crop safety. Initial field tests look promising. Needs to be used in a program with a rotational partner to delay the development of resistance.
- Chlorothalonil (Bravo): Speed registration for use as a rotational product with the strobilurin (azoxystrobin, pyraclostrobin) fungicides.
- Mancozeb (Dithane): Speed registration to reduce the yearly uncertainty regarding the use of this product. This product is needed as a rotational product with the strobilurin (azoxystrobin, pyraclostrobin) fungicides. (Currently available as a Specific Exemption to Section 18 of FIFRA for use on *Alternaria* in Michigan and Wisconsin for 2004).
- Pyraclostrobin/boscalid (Pristine): Classified as a reduced-risk fungicide. Expand studies regarding its efficacy and overall crop safety. Initial field tests look promising. Needs to be used in a program with a rotational partner to delay the development of resistance.

Educational needs:

- As disease forecasting systems or other management tools are developed, provide workshops and demonstration plots.
- Emphasize the importance of alternating fungicides in a program, especially when using azoxystrobin and pyraclostrobin.

2. BOTRYTIS BLIGHT (*Botrytis cinerea*)

The pathogen affects the leaves, flowers, and fruit, leading to defoliation of plants and poor seed set. When conditions are favorable, plant death occurs. Symptoms include rapidly enlarging, water-soaked lesions, often starting at the leaf tip and spreading back along the midrib. The fungus often sporulates on the diseased tissue, producing a fuzzy gray mold. This disease is a particularly severe problem in plantings older than 2 years.

B2 carcinogenic fungicides currently registered for Botrytis blight:

- None identified.

Other fungicides currently registered for Botrytis blight:

- Fenhexamid (Elevate): Efficacy – good to excellent. Classified as a reduced-risk

pesticide. Available to growers for non-food use only. Must be used preventively and frequently when weather conditions favor disease. Should be used in alternation with other products to delay pathogen resistance. Only four applications are allowed per season. This product is not readily available to growers because local suppliers do not carry it in stock because it is not used on other crops in the region.

Other pest management aids for Botrytis blight:

- Azoxystrobin (Quadris): Efficacy – fair. Label does not include *Botrytis*. Azoxystrobin must be used in alternation with fungicides of varying modes of action to delay resistance. Must be used in alternation with a highly effective *Botrytis*-controlling fungicide.
- Iprodione (Iprodione, Rovral): Efficacy – good to poor. Documented pathogen resistance makes this a risky product to use. When used, it should be alternated with products that have a different mode of action.
- Growers currently limit garden size to enhance air flow and movement to reduce the environmental conditions that favor disease development.
- Scout and time the initiation of fungicide sprays to the occurrence of first disease symptoms.
- Apply fungicide sprays preventively when weather favors disease. Frequent rainfall, high humidity and an extended duration of leaf wetness exacerbate disease.
- Rotate crops to avoid pathogen buildup.

Pipeline pest management tools for Botrytis blight:

- Chlorothalonil (Bravo): Efficacy – good to excellent. A Specific Exemption to Section 18 of FIFRA for use of chlorothalonil for *Botrytis* in Michigan and Wisconsin is pending for 2004. Also has good activity against Alternaria blight. Classified as a B2 carcinogen. Must be applied preventively and frequently when weather favors disease. A maximum of six applications is allowed. Registration is pending through completion of an IR-4 project. Growers used this product widely in 2004 through a crisis exemption label issued by the state departments in Michigan and Wisconsin.
- Fluazinam (Omega): Efficacy – good to excellent. Classified as a reduced-risk pesticide. Registration is pending through completion of an IR-4 project.
- Mancozeb (Dithane): Efficacy – fair to poor. Classified as a B2 carcinogen. Historically has been available through a Specific Exemption to Section 18 of FIFRA for control of *Alternaria*. Label does not list *Botrytis*.
- Thiophanate-methyl (Topsin): Efficacy – good. Classified as a B2 carcinogen. Pest resistance is a significant concern. Must be used in rotation with fungicides of varying modes of action to delay the development of resistance. Registration is pending through completion of an IR-4 project.

"To do" list for Botrytis blight:

Research needs:

- Boscalid (Endura): Classified as a reduced-risk fungicide. Expand studies regarding its efficacy and overall crop safety. Initial field tests look promising. Needs to be used in a program with a rotational partner to delay the development of resistance.
- Polyoxin D zinc salt (Endorse): Classified as a biopesticide. Determine the efficacy against *Botrytis* and overall crop safety. Preliminary tests look promising for at least limited control, but further research is needed. Endorse

has the potential to serve as a rotational product for the strobilurins (azoxystrobin, pyraclostrobin) and other fungicides with potential resistance concerns.

- Pyraclostrobin/boscalid (Pristine): Classified as a reduced-risk fungicide. Expand studies regarding its efficacy and overall crop safety. Initial field tests look promising. Needs to be used in a program with a rotational partner to delay the development of resistance.
- Develop a forecasting model to characterize the environmental conditions necessary for disease progression, and time sprays accordingly.
- Test efficacy of new products not registered for ginseng.

Regulatory needs:

- Chlorothalonil (Bravo): Speed registration for use against *Botrytis* as a rotational product with other fungicides. Currently, no effective product is labeled for use during the harvest year. Registration is pending through completion of an IR-4 project. This product should be the cornerstone of a foliar blight management program with access to 8 or more applications.
- Products that allow several applications are needed to maintain protection throughout the growing season (May into October).

Educational needs:

- Assist growers in correctly distinguishing Botrytis blight from Alternaria blight.
- As forecasting systems and other management strategies are developed, provide training workshops and establish demonstration plots.

3. DAMPING-OFF (*Fusarium* spp., *Pythium* spp., *Rhizoctonia solani*)

Root damage may be extensive in seedling and first-year ginseng gardens. Widespread damping-off leads to a significant reduction in plant stands. The pathogens causing this disease are often not identified and therefore have not been well studied. This occurs, in part, because the seedling is so small when infected, that the tissue decays rapidly, making it difficult to isolate the pathogen.

B2 carcinogenic fungicides currently registered for damping-off:

- 1,3-Dichloropropene (Telone II): Efficacy – potentially good. Not tested on ginseng. Classified as a partial methyl bromide alternative.
- 1,3-Dichloropropene/chloropicrin (Telone C-17/C-35): Efficacy – potentially good. Not tested on ginseng. Classified as a partial methyl bromide alternative.

Other fungicides currently registered for damping-off:

- Azoxystrobin (Quadris, Amistar): Efficacy – unknown. Not tested on ginseng. Classified as a reduced-risk pesticide. Registered for *Rhizoctonia*, *Pythium*. May have limited activity, but efficacy data are not available.
- Fludioxonil (Maxim): Efficacy – unknown. Not tested on ginseng. Classified as a reduced-risk pesticide. May suppress *Rhizoctonia* and *Fusarium*. Applied as a seed treatment.

Other pest management aids for damping-off:

- *Bacillus subtilis* (Kodiak): Efficacy – unknown. Not tested on ginseng. Classified as a biopesticide. May suppress *Rhizoctonia* and *Fusarium*. Applied as a seed treatment.
- *Gliocladium virens* (SoilGard): Efficacy – unknown. Not tested on ginseng. Classified as a biopesticide. May suppress *Rhizoctonia* and *Pythium*. Applied as an

in-furrow treatment.
- Select well-drained sites for garden establishment.
- Rotate crops to avoid pathogen buildup.

Pipeline pest management tools for damping-off:

- Fluazinam (Omega): Efficacy – good for *Rhizoctonia*. Classified as a reduced-risk pesticide. May suppress *Fusarium*. Registration is pending through completion of an IR-4 project.
- Thiophanate-methyl (Topsin): Efficacy – poor for *Rhizoctonia*. Classified as a B2 carcinogen. May suppress *Fusarium* and *Rhizoctonia*. Registration is pending through completion of an IR-4 project.

"To do" list for damping-off:

Research needs:

- Identification of the primary pathogen(s) associated with damping-off.
- Captan (Captan): Classified as a B2 carcinogen. Effective against *Phytophthora*, and *Pythium*, and appears to suppress *Rhizoctonia*. Need efficacy data for *Fusarium*.
- Flutolanil (Moncut): Effective against *Rhizoctonia*. Data needed for *Fusarium* and other damping-off pathogens.
- Iprodione (Iprodione, Rovral): Data needed on effectiveness when sprayed on seedlings following emergence. Classified as a B2 carcinogen. May suppress *Rhizoctonia*.
- Polyoxin D zinc salt (Endorse): Efficacy – excellent for *Rhizoctonia*, poor for *Fusarium*, no control of *Pythium*. Classified as a biopesticide.
- Determine which products can be used effectively as seed treatments and are safe for emerging seedlings.
- Determine the compatibility of biological agents used as seed treatments with chemical fungicides.

Regulatory needs:

- Obtain a non-food use of captan as soon as possible.
- Obtain a non-food use of polyoxin D zinc salt (Endorse) as soon as possible.
- Speed registration of effective products using crop groupings whenever possible.
- Obtain new products through a non-food use label whenever possible to expedite their availability.

Educational needs:

- Emphasize the importance of diagnostics as a tool in identifying and managing damping-off.
- Explain the connection between seed quality, seed processing, and damping-off pathogens.

4. DISAPPEARING ROOT ROT (*Cylindrocarpon destructans*)

This is a major pathogen of cultivated ginseng and occurs yearly. The pathogen infects only the roots. Diseased plants often fail to emerge in the spring. Small, discolored, gold to brown areas appear on the root surface in the early stages of infection. The root develops a dark brown discoloration at the infection site during the more advanced stages of the disease. This pathogen is responsible for widespread, devastating plant losses. Even though this pathogen is emerging as a leading cause of root rot, effective

fungicides are not registered.

B2 carcinogenic fungicides currently registered for disappearing root rot:

- 1,3-Dichloropropene (Telone II): Efficacy – unknown. Not tested on ginseng. Classified as a partial methyl bromide alternative.
- 1,3-Dichloropropene/chloropicrin (Telone C-17/C-35): Efficacy – unknown. Not tested on ginseng. Classified as a partial methyl bromide alternative.

Other fungicides currently registered for disappearing root rot:

- Pyraclostrobin (Cabrio EG): Efficacy – poor. Classified as a reduced-risk fungicide. Labeled for use on ginseng but does not list *C. destructans*.

Other pest management aids for disappearing root rot:

- Rotate crops to avoid pathogen buildup.

Pipeline pest management tools for disappearing root rot:

- Fludioxonil (Scholar): Efficacy – good. Classified as a reduced-risk fungicide.
- Thiophanate-methyl (Topsin): Efficacy – good. Classified as a B2 carcinogen. Registration is pending through completion of an IR-4 project.

"To do" list for disappearing root rot:

Research needs:

- Research the epidemiology of the pathogen to better develop effective management strategies.
- Test registered and unregistered products for efficacy.
- Determine efficient and effective methods of applying fungicides to the root zone.
- Determine whether this pathogen is endemic or introduced.
- Do not use straw grown on ground previously planted with ginseng to mulch new beds, due to potential for pathogen spread.
- Investigate different types of mulches and determine whether they impact disease development.

Regulatory needs:

- Obtain a non-food use of fludioxonil (Scholar) as soon as possible and pursue a food use label through IR-4. This is a top priority among ginseng growers.
- Obtain a non-food use of polyoxin D zinc salt (Endorse).
- Speed registration of products determined to be effective against this pathogen.
- Several fungicides are needed to ensure protection throughout the growing season.

Educational needs:

- Work closely with growers to implement new management tools as soon as they are developed.
- Utilize demonstration plots with grower cooperators to highlight effective products and management strategies.

5. PHYTOPHTHORA FOLIAR BLIGHT AND ROOT ROT (*Phytophthora cactorum*)

This disease is one of the most serious problems of ginseng. Both the roots and the foliage can become infected. Infection of the roots results in a light brown water-soaked lesion on the surface of the root that expands rapidly and completely destroys the root. If the leaflets become infected, the plant will collapse downward from the base of the petiole. This pathogen can be seed-borne. Pathogen resistance to fungicides is a primary concern.

B2 carcinogenic fungicides currently registered for Phytophthora foliar blight and root rot:

- 1,3-Dichloropropene (Telone II): Efficacy – unknown. Not tested on ginseng. Classified as a partial methyl bromide alternative.
- 1,3-Dichloropropene/chloropicrin (Telone C-17/C-35): Efficacy – unknown. Not tested on ginseng. Classified as a partial methyl bromide alternative.

Other fungicides currently registered registered for Phytophthora foliar blight and root rot:

- Fosetyl-al (Aliette): Efficacy – fair. Specific to oomycetes and does not have broad-spectrum activity. Should be alternated with products with a different mode of action.
- Mefenoxam (Ridomil): Efficacy – good to poor. Pathogen resistance has been documented and is prevalent in Wisconsin. Classified as a reduced-risk pesticide.
- Salts of phosphorous acid (Agri-Fos, Phostrol): Efficacy – fair. Classified as a biopesticide. Specific to oomycetes and does not have broad-spectrum activity.

Other pest management aids registered for Phytophthora foliar blight and root rot:

- Utilize only clean, treated, disease-free seed.
- Site selection is important to ensure good drainage and ventilation.
- Clean equipment after working in an infested garden to limit spread among gardens.
- Do not plant in a site where ginseng was previously grown.
- Rotate crops to avoid pathogen buildup.

Pipeline pest management tools registered for Phytophthora foliar blight and root rot:

- Dimethomorph (Acrobat): Efficacy – good to fair. Especially helpful for the foliar blight phase of this disease. Also effective against root rot when used as a drench. Registration is pending through completion of an IR-4 project.
- Mancozeb/zoxamide (Gavel): Efficacy – good to fair. Mancozeb is classified as a B2 carcinogen. Especially helpful for the foliar blight phase of this disease. Also helpful in suppressing root rot when applied as a drench. A Specific Exemption to Section 18 of FIFRA for use on *Phytophthora in* Michigan and Wisconsin was granted for 2004.

"To do" list for Phytophthora foliar blight and root rot:

Research needs:

- Test registered and unregistered products for efficacy.
- Test cymoxanil (Curzate 60DF) for efficacy. This product looked promising in a preliminary trial, but additional data are needed.
- Determine the specific environmental conditions that favor Phytophthora foliar blight and root rot.
- Identify effective, efficient methods of applying fungicides to the root zone (i.e., drip application).
- Determine whether fumigants can be used as a disease management tool.
- Establish a seed testing and treatment program.

Regulatory needs:

- Obtain a non-food use of captan as soon as possible and pursue a food use label through IR-4. This is a top priority among ginseng growers.
- Speed registration of products as they are identified as effective and safe.
- Several fungicides are needed to alternate in a program for season-long control to reduce the risk of pathogen resistance.

- Products that allow several applications are needed to maintain protection throughout the growing season (May into October).

Educational needs:

- Emphasize the importance of correct and timely pathogen diagnosis to ensure appropriate fungicide selection.
- Instruct growers on good field sanitation to limit pathogen spread.
- Provide education regarding the development and management of pathogen resistance to fungicides.
- Distribute information regarding *Phytophthora* as a potential seed contaminant.
- Provide an in-depth workshop regarding the biology of the pathogen so control measures can be understood and better implemented.

5. POWDERY MILDEW (*Erysiphe* sp.)

Symptoms include a powdery, white, superficial spots on the upper leaf surfaces. Infected tissue turns reddish purple. Leaves become yellow and may drop. Early and severe infection may reduce seed production, fresh weight and winter hardiness. Currently being managed through Botrytis and Alternaria blight management programs. Favored by cool temperatures in the spring and limited by warmer temperatures of July and August.

B2 carcinogenic fungicides currently registered for powdery mildew:

- None identified.

Other fungicides currently registered for powdery mildew:

- Azoxystrobin (Quadris, Amistar): Efficacy – good. Classified as a reduced-risk fungicide. Widely used for control of Alternaria blight. Development of pathogen resistance is a significant concern. To delay the development of resistance, this fungicide needs to be used in alternation with a fungicide with a different mode of action.
- Neem oil (Trilogy): Efficacy – potentially fair to poor. Not tested on ginseng. Classified as a biopesticide. Not used by growers.
- Pyraclostrobin (Cabrio): Efficacy – good. Widely used to control Alternaria blight. Classified as a reduced-risk fungicide. Development of pathogen resistance is a significant concern. To delay the development of resistance, this fungicide needs to be used in alternation with a fungicide with a different mode of action.

Other pest management aids for powdery mildew:

- Management programs currently in place for *Botrytis* and *Alternaria* management are highly effective for powdery mildew control.
- Growers currently limit garden size to enhance air flow and movement to reduce the environmental conditions that favor disease development.
- Scout and time initiation of spraying to first disease symptoms.
- Rotate crops to avoid pathogen buildup.

Pipeline pest management tools for powdery mildew:

- Chlorothalonil (Bravo): Efficacy – good to excellent. Also has good activity against Alternaria and Botrytis blights. A Specific Exemption to Section 18 of FIFRA for use of chlorothalonil for *Botrytis* in Michigan and Wisconsin is pending for 2004. Used widely by growers through a crisis exemption granted by the state departments in Michigan and Wisconsin to limit disease epidemics resulting from unusually wet weather in 2004. Classified as a B2 carcinogen. Must be applied preventively and

frequently when weather favors disease. A maximum of six applications is allowed. Registration is pending through completion of an IR-4 project.

- Fluazinam (Omega): Efficacy – good to excellent. Classified as a reduced-risk pesticide. Registration is pending through completion of an IR-4 project.
- Mancozeb (Dithane): Efficacy – good. Classified as a B2 carcinogen. Historically has been available through a Specific Exemption to Section 18 of FIFRA.
- Thiophanate-methyl (Topsin): Efficacy – good. Classified as a B2 carcinogen. Pest resistance is a significant concern. Must be used in rotation with fungicides of varying modes of action to delay the development of resistance. Registration is pending through completion of an IR-4 project.

"To do" list for powdery mildew:

Research needs:

- Investigate the epidemiology of this pathogen.

Regulatory needs:

- Speed registration of broad spectrum fungicides such as chlorothalonil (Bravo) and mancozeb (Dithane).
- None identified as long as the products relied on for other foliar blights are maintained.

Educational needs:

- Alert growers that without a solid foliar blight management program, powdery mildew could become a significant problem.

6. SCLEROTINIA WHITE ROT (*Sclerotinia sclerotiorum*)

This disease causes a stem and root rot of ginseng. Infected foliage wilts, becomes discolored, dried and shriveled. Black sclerotia often form on infected plant parts. The pathogen is a major problem in Michigan wood lots.

B2 carcinogenic fungicides currently registered for Sclerotinia white rot:

- 1,3-Dichloropropene (Telone II): Efficacy – unknown. Not tested on ginseng. Classified as a partial methyl bromide alternative.
- 1,3-Dichloropropene/chloropicrin (Telone C-17/C-35): Efficacy – unknown. Not tested on ginseng. Classified as a partial methyl bromide alternative.

Other fungicides currently registered for Sclerotinia white rot:

- None identified.

Other pest management aids for Sclerotinia white rot:

- Rotate crops to avoid pathogen buildup.

Pipeline pest management tools for Sclerotinia white rot:

- Fluazinam (Omega): Efficacy – unknown. Not tested on ginseng. Classified as a reduced-risk pesticide. Registration is pending through completion of an IR-4 project.
- Thiophanate-methyl (Topsin): Efficacy – unknown. Not tested on ginseng. Classified as a B2 carcinogen. Registration is pending through completion of an IR-4 project.

"To do" list for Sclerotinia white rot:

Research needs:

- Determine environmental conditions that favor white rot.
- Efficacy of products needs to be determined.
- Develop effective and efficient methods of applying fungicides to the root zone

(i.e., drip application).

Regulatory needs:

- Speed registration of products determined to be effective and safe.

Educational needs:

- Provide education regarding the biology of the pathogen and other potential hosts.
- Emphasize the importance of correct and timely diagnosis.

7. SEPTONEMA DISEASE (*Septonema* sp.)

Septonema sp. has been isolated from buds, roots and seedlings of Wisconsin ginseng.

B2 carcinogenic fungicides currently registered for Septonema disease:

- None identified.

Other fungicides currently registered for Septonema disease:

- None identified.

Other pest management aids for Septonema disease:

- None identified.

Pipeline pest management tools for Septonema disease:

- None identified.

"To do" list for Septonema disease:

Research needs:

- Determine whether this pathogen is a significant threat to ginseng. Develop information regarding its epidemiology. If this fungus is an important pathogen, then test fungicides for efficacy and develop cultural methods of control.

Regulatory needs:

- None identified.

Educational needs:

- Inform growers of the presence of this fungus and any relevant management strategies.

8. STROMATINIA BLACK ROT (*Stromatinia panacis*)

A problem only in Michigan wood lots. This disease also infects false solomon's seal, a woodland plant.

B2 carcinogenic fungicides currently registered for Stromatinia black rot:

- None identified.

Other fungicides currently registered for Stromatinia black rot:

- None identified.

Other pest management aids for Stromatinia black rot:

- Rotate crops to avoid pathogen buildup.

Pipeline pest management tools for Stromatinia black rot:

- None identified.

"To do" list for Stromatinia black rot:

Research needs:

- Determine whether registered and unregistered products are effective.
- Develop the information necessary to better understand the disease cycle.

Regulatory needs:

- Speed registration of products that are effective and safe.

Educational needs:

- None identified.

9. VERTICILLIUM WILT (*Verticillium dahliae*)

Affected plants display wilting foliage, and the plant eventually dies. The vascular tissue of infected plant materials is discolored and yellow. This disease is considered a rare problem.

B2 carcinogenic fungicides currently registered for Verticillium wilt:

- 1,3-Dichloropropene (Telone II): Efficacy – unknown. Not tested on ginseng. Classified as a partial methyl bromide alternative.
- 1,3-Dichloropropene/chloropicrin (Telone C-17/C-35): Efficacy – unknown. Not tested on ginseng. Classified as a partial methyl bromide alternative.

Other fungicides currently registered for Verticillium wilt:

- None identified.

Other pest management aids for Verticillium wilt:

- Rotate crops to avoid pathogen buildup.

Pipeline pest management tools for Verticillium wilt:

- None identified.

"To do" list for Verticillium wilt:

Research needs:

- Determine whether the pathogen represents a significant economic threat.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

NEMATODES

1. ROOT-KNOT NEMATODE (*Meloidogyne hapla*)

Mature roots may be deformed, short and branched, and secondary roots abnormally branched and hairy.

Organophospate nematicides currently registered:

- None identified.

Carbamate nematicides currently registered:

- Metam sodium (Vapam): Efficacy – fair to poor.

B2 carcinogenic nematicides currently registered:

- 1,3-Dichloropropene (Telone II): Efficacy – good to fair. Classified as a partial methyl bromide alternative.
- 1,3-Dichloropropene/chloropicrin (Telone C-17, C-35): Efficacy – good to fair. Classified as a partial methyl bromide alternative.

Other nematicides currently registered:

- Dazomet (Basamid): Efficacy – unknown. Not tested on ginseng. Classified as a partial methyl bromide alternative.
- *Myrothecium verrucaria* (DiTera WDG): Efficacy – unknown. Not tested on

ginseng. Supplemental label available for use on ginseng only in Wisconsin. Not used by growers. Classified as a partial methyl bromide alternative and a biopesticide.

Other pest management aids:

- Crop rotation.
- Trap crops (oil seed radish).

Pipeline pest management tools:

- None identified.

"To do" list for nematodes:

Research needs:

- Conduct a survey to identify and determine the nematodes present in Wisconsin's and Michigan's ginseng production.
- Characterize nematode bio-diversity.
- Test fumigants and fumigant alternatives for their ability to limit parasitic nematode populations.

Regulatory needs:

- None identified.

Educational needs:

- Growers are interested in learning which nematodes negatively or positively impact ginseng production.

WILDLIFE PESTS

1. DEER, RACOONS, SKUNKS, TURKEYS.

Pest management tools:

- Fencing, balloons, cannon (noise makers).

Pipeline pest management tools:

- None identified.

"To do" list:

Research needs:

- Study the pattern of turkey movement.
- Develop efficient and effective methods to disturb the nesting habits of turkeys.
- Test racoon repellents.
- Need interior (in garden) baiting material.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

WEEDS

Grasses, yellow nutsedge, dandelion, creeping jennie, lambsquarter, broadleaf weeds, sedges, pigweed, thistles, and raspberry (Michigan only).

1. **PRE-PLANT HERBICIDES**
    - Glyphosate (Roundup, Glyphomax Plus, Touchdown): Efficacy – good to excellent. Kills emerged weeds, very effective against most green plants. Cannot be applied during the harvest year.
2. **POST-EMERGENCE HERBICIDES – BEFORE PLANTING**
    - Glyphosate (Roundup, Glyphomax Plus, Touchdown): Efficacy – excellent. Kills emerged weeds, very effective against most green plants. No pre-activity. Cannot be applied during the harvest year.
3. **PRE- AND POST-EMERGENCE HERBICIDES**
    - None identified.
4. **POST-EMERGENCE HERBICIDES**
    - Fluazifop (Fusilade): Efficacy – good. Kills most annual and perennial grasses. No pre-activity. Cannot be applied during the harvest year.

Other weed management aids:

- Straw mulch.
- Hand weeding – currently the main weed control tool, very expensive.

Pipeline weed management tools:

- DCPA (Dacthal): Pre-emergent herbicide. Classified as a group C possible human carcinogen. Tolerance has been established and ginseng may be added to the label.

"To do" list for weeds:

Research needs:

- Phenmedipham (Spin-Aid EC): Looked promising in a preliminary field trial as a post-emergent herbicide. More crop safety and efficacy data are needed.
- Test new chemistries for efficacy and crop safety.
- Test new techniques for applying fumigants.
- Test new fumigants, including new products for efficacy and crop safety.

Regulatory needs:

- Explore non-food use registrations as soon as safe and effective products are identified.

Educational needs:

- When new products are identified and registered, establish demonstration trials to highlight research findings to growers.

TABLE 1. CLASSIFICATION OF PESTICIDES

Chemical group	Human Risk Assessment
Carbamate	Acetylcholinesterase inhibitor; disrupts the nervous system.
Organophosphate	Acetylcholinesterase inhibitor; disrupts the nervous system.
B2 carcinogen	Likely human carcinogen.
C carcinogen	Possible human carcinogen for which there is limited animal evidence.
D carcinogen	There is inadequate evidence to determine carcinogenicity in humans.
E chemical	Evidence of non-carcinogenicity in humans.

TABLE 2. REGISTERED PESTICIDES FOR GINSENG

Active ingredient	Trade name	Company
PESTICIDES for INSECTS and other invertebrates		
azadirachtin	Neemix 4.5	Certis USA, LLC
diazinon	Diazinon G	numerous companies
imidacloprid	Admire 2 Flowable Insecticide Provado 1.6 Flowable Insecticide	Bayer CropScience
metaldehyde	DeadlineBullets, M-Ps Slugfest All Weather Formula	Amvac Chemical Corporation Monterey Chemical Company
pyrethrins/piperonyl butoxide	Pyrenone Crop Spray	Bayer ES Professional Pest Control
spinosad	SpinTor 2SC	Dow AgroSciences, LLC
NEMATICIDES		
1,3-dichloropropene	Telone II	Dow AgroSciences
1,3-dichloropropene/chloropicrin	Telone C-17/C-35	Dow AgroSciences
metam sodium	Vapam HL	Amvac Chemical Corp.
Myrothecium verrucaria	DiTera WDG (Wisconsin only)	Valent U.S.A. Corp.
FUNGICIDES		
azoxystrobin	Amistar, Quadris	Syngenta Crop Protection, Inc.
Bacillus subtilis	Kodiak	Gustafson, LLC
copper hydroxide	Champ DP Dry Prill, Flowable Kocide Nu-Cop	Nufarm, Inc. E.I. duPont de Nemours and Co. Micro Flo Co.
dichloropropene	Telone II	Dow AgroSciences
dichloropropene/chloropicrin	Telone C-17, C-35	Dow AgroSciences
fenhexamid (non-food use only)	Elevate 50WDG	Arvesta Corporation USA
fludioxonil	Maxim	Syngenta Crop Protection, Inc.
fosetyl-al	Aliette	Bayer CropScience
Gliocladium virens	SoilGard	Certis USA, LLC
hydrogen dioxide	OxiDate	BioSafe Systems
iprodione	Rovral 50WP Rovral brand 4 Flowable Iprodione 4L AG	Bayer CropScience Bayer CropScience Micro Flo Co.
mefenoxam	Ridomil Gold EC Ridomil Gold GR	Syngenta Crop Protection, Inc.
neem oil	Trilogy	Certis CropProtection
pyraclostrobin	Cabrio WG	BASF, Inc.
salts of phosphorous acid	Agri-Fos Phostrol 4.32EC	Agrichem America Nufarm Americas, Inc.
HERBICIDES		
fluazifop	Fusilade DX	Syngenta Crop Protection, Inc.
glyphosate	Round-Up Glyphomax Plus Touchdown	Monsanto Co. Dow AgroScience Syngenta Crop Protection, Inc.

TABLE 3. UNREGISTERED PESTICIDES TESTED ON GINSENG IN MICHIGAN OR WISCONSIN

Fungicides	Pathogens tested[1]							
	Alt	***Bot***	***Cyl***	***Fus***	***Phy***	***Rhi***	***Sep***	***Scl***
boscalid (Endura 70WG)	E	E						–
captan (Captan)		E	G	?	E	G	–	–
chlorothalonil (Bravo Weather Stik 6F)	E	E			P			
Coniothyrium minitans (Contans WG)	–	–			–			?
cyazofamid (Ranman 400SC)	–	–			F-P			
cymoxanil (Curzate 60DF)	–	–			E			
dimethomorph (Acrobat 50WP)	–	–			G			
etridiazole (Terramaster 4EC)	–	–			P			
famoxadone/cymoxanil (Tanos 50DF)					G			
fenamidone (Reason 500SC)					G-F			
fluazinam (Omega 500F)	E	E	P	–	P	G-F		?
fludioxonil (Scholar)	E	G	G	?		G	–	
flutolanil (Moncut)			P	–		G		
mancozeb (Dithane 75DF)	E-G	P			G-F			–
mancozeb/zoxamide (Gavel 75DF)	G				G			
polyoxin D zinc salt (Endorse 2.5WP)	F	E	F-P	–	P	E	–	?
propamocarb (Previcur Flex 6F)	–				P			
pyraclostrobin/boscalid (Pristine 38WG)	E	E			P	G		–
thiophanate-methyl (Topsin)	P	G-F	G	?	P	P	–	?
triflumizole (Terraguard 50W)	–					F	–	
zoxamide (Zoxium 80WP)	–	–			F-P			

[1] Key for pathogens: *Alt = Alternaria, Bot = Botrytis, Cyl = Cylindrocarpon, Fus = Fusarium, Phy = Phytophthora, Rhi = Rhizoctonia, Sep = Septonema, Scl = Sclerotium*.

[2] Efficacy rating symbols: E = excellent (90-100% control), G = good (75-89% control), F = fair (60-74%), P = poor (<60% control), ? = no data, but successful on related organisms, – = not applicable and /or used.

TABLE 4. DESCRIPTION OF PESTS AND PATHOGENS OF GINSENG

Pest/Pathogen	Symptoms
INSECT PESTS AND OTHER INVERTEBRATES	
Aphids	Aphids pierce foliage and suck out the plant sap, and may cause twisting and distortion of new growth.
Cutworms	Minor pest of ginseng. Damage occurs to foliage only. Cutworms feed on stems, girdling young plants and chewing ginseng tops.
Four-lined plant bugs	Fresh feeding spots (1-2 mm diameter) on foliage are initially dark colored, but quickly become white or tan and papery. Spots can coalesce.
Leaf rollers	Larvae partially chew the petiole to allow the leaf to wilt, then fold the leaf around themselves. Larvae feed on ginseng during the day and shelter in the rolled leaf at night.
Millipedes	An innocuous feeder of composting vegetation.
Slugs	Ragged holes in the leaves and slime trails are symptoms of slug feeding.
Spittle bugs	Spittle bugs suck plant sap. Larvae of spittle bugs produce and shelter in produce frothy "spittle" on plant stems.
Thrips	Minor pest of ginseng. Most damage occurs to flower heads.
Treehoppers	Feeding can cause seedlings to collapse.
White grubs	Grubs feed below the surface on plant roots.
Wireworms	Wireworms feed below the surface on plant roots.
DISEASE PATHOGENS	
Alternaria blight (*Alternaria panax*)	Disease affects production throughout North America and Asia. If not controlled can produce severe epidemics. Alternaria blight may kill young plants or limit the yield of harvested roots by causing premature defoliation. Lesions often appear to originate at the base of the stem. Leaves will collapse and turn red or yellow. In seedlings, the entire plant collapses resulting in a damped-off appearance.
Botrytis blight (*Botrytis cinerea*)	The pathogen affects the leaves, flowers, and fruit, leading to defoliation of plants and poor seed set. Symptoms include rapidly enlarging, water-soaked lesions, often starting at the leaf tip and spreading back along the midrib. The fungus often sporulates on the rotted tissue, producing a fuzzy gray mold.
Damping-off, seed decay (*Fusarium* spp., *Pythium* spp., *Rhizoctonia solani*)	Root damage is often extensive in first-year ginseng gardens. Damping-off can lead to a significant reduction in plant stands. These diseases are often poorly diagnosed and have not been well studied.

Pest/Pathogen	Symptoms
Disappearing root rot (*Cylindrocarpon destructans*)	A major pathogen of cultivated ginseng. The disease infects only the root portions of the plant. Diseased plants often fail to emerge in the spring. Small, discolored, gold to brown areas appear on the root surface in the early stages of infection. The root develops a dark brown discoloration at the infection sites during the more advanced stages of the disease.
Phytophthora root rot (*Phytophthora cactorum*)	One of the most serious diseases of ginseng. Infection can occur both to the roots and to the foliage. Infection of the roots causes a light brown water-soaked lesion on the surface of the root that spreads rapidly and completely destroys the root. Leaflets on the infected plant collapse downward from the base of the petiole.
Powdery mildew	Superficial, white, powdery growth on the upper leaf surfaces with infected tissue turning reddish purple. Leaves may turn yellow and drop.
Sclerotinia white rot (*Sclerotinia sclerotiorum*)	This disease causes a stem and root rot of ginseng. Infected foliage wilts, discolors and dries up. Black sclerotia often form on infected plant parts.
Septonema disease (*Septonema* sp.)	Not well understood. Appears to cause a superficial reddening of the root tissue, resulting in decreased value due to poor aesthetic appeal. Possibly involved in the damping-off complex.
Stromatinia black rot (*Stromatinia panacis*)	Infected plants may fail to emerge in the spring. Roots are intact and black on the surface, with white, water and spongy interior. Black bumps (sclerotia) may form on the surface and in the interior. Problem in wood lots in Michigan.
Verticillium wilt (*Verticillium dahliae*)	Infected plants display wilting of the foliage. The wilting eventually kills the plant. The vascular tissue of infected plant materials is discolored yellow.
NEMATODES	
Northern root-knot nematode (*Meloidogyne hapla*)	Mature roots may be deformed, short and branched, and secondary roots abnormally branched and hairy.
WILDLIFE PESTS	
Deer	Bed down in ginseng gardens.
Racoons, Skunks	Disrupt mulch, uproot seedlings. Dig 1,500-2,000 holes per night.
Turkeys	Disrupt mulch. Break crowns during scratching.
WEEDS	
Annuals	Grasses, lambsquarter.
Perennials	Grasses, dandelion, yellow nutsedge, creeping jennie, raspberry.

TABLE 5. ADVANTAGES AND DISADVANTAGES OF PESTICIDES FOR GINSENG

Active	Pest	Advantages/Disadvantages
INSECTICIDES		
azadirachtin	aphid, cutworm, 4-lined plant bug, leaf roller, millipede, spittle bug, thrips, treehopper, white grub, wireworm	• biopesticide
diazinon	cutworm, millipede, white grub	• organophosphate • toxic to bees, fish • long residual time, good efficacy
dichloropropene	wireworm	• B2 carcinogen • cannot use on heavy soil • worker personal protective equipment required • water setbacks • fumigant • expensive, requires costly equipment • specific temperature requirements limit its use • also used to control soil-borne diseases and nematodes
dichloropropene/ chloropicrin	wireworm	• B2 carcinogen • worker personal protective equipment required • water setbacks • fumigant • expensive, requires costly equipment • specific temperature requirements limit its use • also used to control soil-borne diseases and nematodes
imidacloprid	aphid, cutworm, 4-lined plant bug, leaf roller, millipede, spittle bug, thrips, treehopper, white grub, wireworm	• organophosphate alternative • systemic soil treatment • expensive
metaldehyde	slug	• avoid contact with plants • used between rows
pyrethrins/ piperonyl butoxide	aphid, spittle bug, treehopper, white grub, wireworm	• may increase aphid populations • no preharvest interval • nontoxic to humans, animals • minimally disruptive to beneficials • short residual • only 1-3 applications per season • not readily available in Michigan

Active	Pest	Advantages/Disadvantages
spinosad	aphid, cutworm, 4-lined plant bug, leaf roller, millipede, spittle bug, treehopper, white grub, wireworm	• reduced-risk insecticide • new product • used in resistance management programs • expensive • short pre-harvest interval (1 day)
FUNGICIDES		
azoxystrobin	Alternaria blight damping-off (*Pythium*, *Rhizoctonia*)	• reduced-risk fungicide • potential resistance issues • known control against *Alternaria*
Bacillus subtilis	damping-off	• biopesticide • seed treatment only
copper hydroxide	Alternaria blight	• potential phytotoxicity • limited control of *Alternaria*
dichloropropene	damping-off, disappearing root rot, Phytophthora foliar blight and root rot, Sclerotinia white rot, Verticillium wilt	• B2 carcinogen • cannot use on heavy soil • worker personal protective equipment required • water setbacks • fumigant • expensive, requires costly equipment • specific temperature requirements limit its use • also used to control insects and nematodes
dichloropropene/ chloropicrin	damping-off, disappearing root rot, Phytophthora foliar blight and root rot, Sclerotinia white rot, Verticillium wilt	• B2 carcinogen • worker personal protective equipment required • water setbacks • fumigant • expensive, requires costly equipment • specific temperature requirements limit its use • also used to control insects and nematodes
fenhexamid	Botrytis leaf blight	• reduced-risk fungicide • non-food use only • cannot be used on crop to be harvested • limited range of pathogens controlled • only 4 applications allowed per season
fludioxonil	damping-off	• reduced-risk • seed treatment only
fosetyl-al	Phytophthora foliar blight and root rot	• limited efficacy • pathogen-specific
Gliocladium virens	damping-off	• biopesticide • in-furrow treatment only
hydrogen dioxide	Alternaria blight	• biopesticide • not tested on ginseng • not used by growers • limited efficacy when tested on other crops

Active	Pest	Advantages/Disadvantages
iprodione	Alternaria blight	• B2 carcinogen • resistance issues • effective against sensitive pathogen populations
mefenoxam	Phytophthora foliar blight and root rot	• reduced-risk fungicide • resistance documented and widespread
neem oil	Alternaria blight	• biopesticide • efficacy data and use pattern lacking for ginseng • very limited efficacy demonstrated for the same pathogens on other crops
pyraclostrobin	Alternaria blight	• reduced-risk fungicide • potential resistance issues. • known control against *Alternaria*
salts of phosphorous acid	Phytophthora foliar blight and root rot	• biopesticide • limited efficacy • pathogen-specific
NEMATICIDES		
dazomet	Nematodes	• partial methyl bromide alternative
dichloropropene	Nematodes	• B2 carcinogen • cannot use on heavy soil • worker personal protective equipment required • water setbacks • fumigant • expensive, requires costly equipment • specific temperature requirements limit its use • also used to control soil-borne diseases and nematodes
dichloropropene/ chloropicrin	Nematodes	• B2 carcinogen • worker personal protective equipment required • water setbacks • fumigant • expensive, requires costly equipment • specific temperature requirements limit its use • also used to control soil-borne diseases and nematodes
metam sodium	Nematodes	• carbamate • highly efficient • very expensive • controls bacteria, fungi, weeds, soil insects • fumigant or chemigant • toxic to fish
Myrothecium verrucaria	Nematodes	• biopesticide and partial methyl bromide alternative • supplemental label for use only in Wisconsin

Active	Pest	Advantages/Disadvantages
HERBICIDES		
fluazifop	Postemergence grasses	• limits grasses for only 1 year • limit 6 pt/A/year • broadleaf crops are tolerant, but higher rate needed for quackgrass • cannot apply during the harvest year
glyphosate	Postemergence grasses and broadleaves	• limits weeds for only 2 weeks • excellent efficacy, non-residual • broad spectrum, excellent on perennials • slightly toxic to birds, practically nontoxic to fish, aquatics, honeybees • apply before planting only

TABLE 6. EFFICACY OF PEST MANAGEMENT TOOLS FOR CONTROL OF INSECTS AND OTHER INVERTEBRATE PESTS ON GINSENG

Management tool	Insect/invertebrate pests of ginseng[1]										
	Ap	CW	4L	LR	Mi	Sl	SB	Tp	TH	WG	WW
B2 CARCINOGENIC INSECTICIDES REGISTERED											
dichloropropene (Telone II)	–	–	–	–	–	–	–	–	–	–	G
dichloropropene/chloropicrin (Telone C-17/C-35)	–	–	–	–	–	–	–	–	–	–	G
ORGANOPHOSPHATE INSECTICIDES REGISTERED											
diazinon (Diazinon G)	–	E-G	–	–	U	–	–	–	–	G	–
OTHER INSECTICIDES REGISTERED											
azadirachtin (Neemix 4.5)	F-P	P	U	P	P	–	F-P	U	P	P	P
imidacloprid (Admire, Provado)	G	P	U	P	P	–	G	U	G	G	F
metaldehyde (Deadline, Slugfest)	–	–	–	–	–	G	–	–	–	–	–
pyrethrins/piperonyl butoxide (Pyrenone)	G	–	–	–	–	–	F-P	–	G	P	P
spinosad (SpinTor)	U	G	U	G	P	–	G	–	G	P	P
PIPELINE PEST MANAGEMENT TOOLS											
lambda-cyhalothrin (Warrior)	?	?	?	?	–	–	?	?	?	–	–
pymetrozine (Fulfill)	?	–	–	–	–	–	–	–	–	–	–
thiamethoxam (Actara, Platinum)	?	?	?	?	–	–	?	–	?	–	–
OTHER PEST MANAGEMENT AIDS											
cover crops	–	–	–	–	–	–	–	–	–	–	–
diatomaceous earth	–	–	–	–	–	F	–	–	–	–	–
fumigation	–	–	–	–	?	–	–	–	–	?	–
remove weeds around gardens	?	?	–	–	–	?	–	–	–	–	–
sawdust mulch	–	–	–	–	–	F	–	–	–	–	–
scouting	?	?	?	?	?	?	?	?	?	?	?
site selection	?	?	?	?	?	?	?	?	?	?	?
till site before planting	–	–	–	–	–	–	–	–	–	?	–

[1] Key to insect/invertebrate pests: Ap = aphids, CW = cutworms, 4L = four-lined plant bugs, Mi = millipedes, Sl = slugs, SB = spittle bugs, Tp = thrips, TH = treehoppers, WG = white grubs, WW = wireworms.

[2] Efficacy rating symbols: E = excellent (90-100% control), G = good (75-89% control), F = fair (60-74%), P = poor (<60% control), ? = no data, but successful on related organisms, – = not applicable and /or used, U = unknown.

TABLE 7. EFFICACY OF PEST MANAGEMENT TOOLS FOR CONTROL OF FUNGAL PATHOGENS ON GINSENG

Management tool	Diseases of ginseng[1]								
	Alt	Bot	DO	DRR	Phy	PM	Scl	SBR	Vert
B2 CARCINOGENIC FUNGICIDES REGISTERED									
dichloropropene (Telone II)	–	–	?	?	?	–	?	?	?
dichloropropene/chloropicrin (Telone C-17/C-35)	–	–	?	?	?	–	?	?	?
iprodione (Rovral)	E-G	G-F	–	–	–	–	–	–	–
OTHER FUNGICIDES REGISTERED									
azoxystrobin (Quadris, Amistar)	E	F	–	–	–	E	–	–	–
Bacillus subtilis (Kodiak) seed treatment	–	–	?	–	–	–	–	–	–
copper hydroxide (Champ, Kocide, Nu-Cop)	G-F	F	–	–	–	G	–	–	–
fenhexamid (Elevate)	–	E	–	–	–	–	–	–	–
fludioxonil (Maxim) seed treatment	–	–	?	–	–	–	–	–	–
fosetyl-al (Aliette)	–	–	–	–	F	–	–	–	–
Gliocladium virens (SoilGard) in-furrow	–	–	–	–	–	–	–	–	–
hydrogen dioxide (OxiDate)	P	–	–	–	–	–	–	–	–
mefenoxam (Ridomil)	–	–	E-P	–	E-P	–	–	–	–
neem oil (Trilogy)	P	–	–	–	–	–	–	–	–
pyraclostrobin (Cabrio WG)	E	F	?	P	–	E	–	–	–
salts of phosphorous acid (Agri-Fos, Phostrol)	–	–	–	–	F	–	–	–	–
PIPELINE PEST MANAGEMENT TOOLS									
chlorothalonil (Bravo)	E	E	–	–	P	E	–	–	–
dimethomorph (Acrobat)	–	–	P	–	G	–	–	–	–
fluazinam (Omega)	E	E	P	P	P	E	–	–	–
mancozeb (Dithane)	G	F-P	–	–	F-P	E	–	–	–
mancozeb/zoxamide (Gavel)	G	F-P	G	–	G	E	–	–	–
thiophanate-methyl (Topsin)	P	F	F-P	G	–	E	–	–	–
OTHER PEST MANAGEMENT AIDS									
good ventilation	F	F	–	–	F	F	F	–	–
increased drainage	F	F	F	F	F	–	F	–	–
limit garden size	F	F	–	–	F	F	–	–	–
sanitation	–	–	F	F	F	–	F	–	F
scouting	F	F	–	–	F	F	–	–	–
seed treatments	–	–	F	F	F	–	–	–	–
time sprays to initial disease occurrence	P	P	P	P	P	F	P	P	P

[1] Key for diseases: Alt = Alternaria leaf blight; Bot = Botrytis leaf blight; DO = damping-off (including *Rhizoctonia*, *Pythium*); DRR = disappearing root rot; Phy = Phytophthora foliar blight and root rot; PM = powdery mildew; Scl = Sclerotinia white rot; SBR = Stromatinia black rot; Vert=Verticillium wilt.

[2] Efficacy rating symbols: E = excellent (90-100% control), G = good (75-89% control), F = fair (60-74%), P = poor (<60% control), ? = no data, but successful on related other crops, – = not applicable and /or used.

TABLE 8. EFFICACY OF PEST MANAGEMENT TOOLS FOR CONTROL OF NEMATODE PESTS ON GINSENG

Management tool	Northern root-knot nematode
B2 CARCINOGENIC NEMATICIDES REGISTERED	
dichloropropene (Telone II)	G-F
dichloropropene/chloropicrin (Telone C-17/C-35)	G-F
CARBAMATE NEMATICIDES REGISTERED	
metam sodium (Vapam)	G-F
OTHER NEMATICIDES REGISTERED	
dazomet (Basamid)	U
Myrothecium verrucaria (DiTera WDG)	U

[1] Efficacy rating symbols: Efficacy rating symbols: E = excellent (90-100% control), G = good (75-89% control), F = fair (60-74%), P = poor (<60% control), ? = no data, but successful on related organisms, – = not applicable and /or used, u = unknown.

TABLE 9. EFFICACY OF PEST MANAGEMENT TOOLS FOR CONTROL OF WEEDS ON GINSENG

Management tool	Annual weeds		Perennial weeds	
	Broadleaf	Grass	Broadleaf	Grass
PRE-PLANT HERBICIDES				
glyphosate (Roundup, Glyphomax Plus, Touchdown)	G	G	G	G
POST-EMERGENCE HERBICIDES – Before Planting				
glyphosate (Roundup, Glyphomax Plus, Touchdown)	G	G	G	G
POST-EMERGENCE HERBICIDES				
fluazifop (Fusilade DX)	none	G	none	G
OTHER PEST MANAGEMENT PRACTICES				
cover crops	?	?	?	?
wind breaks	–	–	–	–
crop rotation	?	?	?	?
fall tillage (in conjunction with herbicide treatment)	?	?	?	?
herbicide rotation to reduce resistance	–	–	–	–
straw mulch	F	F	F	F
hand weeding	E	E	E	E

[1] Efficacy rating symbols: E = excellent (90-100% control), G = good (75-89% control), F = fair (60-74%), P = poor (<60% control), ? = no data, but successful on related organisms, – = not applicable and /or used, * = no control over composites, wild carrot and nutsedge, ** = effective on only some grasses, *** = weak on quack grass and no nutsedge control.

TABLE 10. GENERAL TIMELINE FOR CROP STAGES AND WORKER ACTIVITIES

Prior to planting	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Site selection, soil sampling, soil survey (several years prior)				■	■	■	■		
Soil prep (two years prior)								■	■
Roundup (1-2 years prior)			■		■		■		
Year 0 (planting)	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Fumigation				■					
Fertilization				■				■	■
Land prep (MI)		■	■	■	■	■	■		
Posts				■	■	■	■	■	■
Bed formation				■	■	■	■	■	
Planting (seeding)					■	■	■	■	
Straw mulch					■	■	■	■	
Diazinon, slug bait (1-2 appl) . . .				■	■	■			
Herbicide application (grass) . . .							■		
Roundup							■		
Year 1 (seedling)	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Slug bait (diazinon)		■	■	■	■	■	■		
Fertilization		■	■						
Shade cloth		■	■						
Fill gutters with gravel		■	■						
Foliar fungicide program			■	■	■	■	■	■	
Root rot fungicides		■	■	■	■	■	■	■	
Weed control (herbicide)				■	■	■			
Weed control (Dacthal)		■			■				
Dynaweed (corn glutamyl)		■							
Hand weeding (WI)				■	■	■			
Hand weeding (MI)					■	■			
Roundup								■	■
Shade removed							■	■	
Fertilization (soil sampling)								■	■
Years 2-3 (2-3 year old plants)	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Plant emergence		■	■						
Slug bait (diazinon)		■	■	■	■	■	■		
Bloom				■	■				

Years 2-3 (2-3 year old plants)	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Pyrenones not widely used (toxic to bees)									
Shade cloth									
Fill gutters									
Foliar fungicide program									
Root rot fungicides									
Weed control 2 year (herbicide)									
Weed control (Dacthal)									
Dynaweed (corn glutamyl)									
Hand weeding									
Roundup									
Shade removed									
Fertilization (soil sampling)									
Bloom period									
Seed harvested (3 year olds)									
Straw removed prior to harvest (mechanical)									
3 yr old roots harvested									
Year 4 and beyond (4 year and older plants)	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Plant emergence									
Slug bait (diazinon)									
Bloom									
Pyrenones not widely used (toxic to bees)									
Shade cloth									
Fill gutters									
Foliar fungicide program									
Root rot fungicides									
Weed control (herbicide)									
Weed control (Dacthal)									
Dynaweed (corn glutamyl)									
Hand weeding									
Roundup									
Shade removed									
Fertilization (soil sampling)									
Bloom period									

Year 4 and beyond (4 year and older plants)	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Seed harvested									
Straw removed prior to harvest (mechanical)									
Roots harvested									

TABLE 11. GENERAL TIMELINE OF DISEASE, INSECT, NEMATODE AND WEED PESTS

DISEASES	Apr	May	Jun	Jul	Aug	Sep	Oct
Alternaria blight	■	■	■	■	■	■	■
Botrytis blight	■	■	■	■	■	■	■
Damping-off	■	■	■				
Disappearing root rot			■	■	■	■	■
Phytophthora	■	■	■	■	■	■	■
Powdery mildew . . .		■	■	■			
Sclerotinia white rot .			■	■	■	■	■
Stromatinia black rot			■	■	■	■	■
Verticillium wilt				■	■	■	■
INSECTS	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Aphids				■	■		
Cutworms		■	■				
Four-lined plant				■	■		
Leaf rollers			■	■			
Millipedes		■	■	■	■	■	
Slugs		■	■	■	■	■	
Spittle bugs			■	■	■	■	
Treehoppers			■	■			
White Grubs		■	■				
Wireworms		■	■				
NEMATODES	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Root-knot nematode		■	■	■	■	■	
WEEDS	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Grasses		■	■	■	■	■	
Broadleaf		■	■	■	■	■	
Raspberry (MI)		■	■	■	■	■	
Sedges		■	■	■	■	■	
Creeping jennie			■	■	■	■	
Dandelions	■	■	■	■	■	■	
Pigweed	■	■	■	■	■	■	
Lambsquarter		■	■	■	■	■	
Thistles		■	■	■	■	■	■
Yellow nutsedge		■	■	■	■	■	