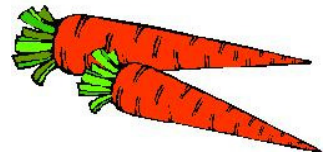
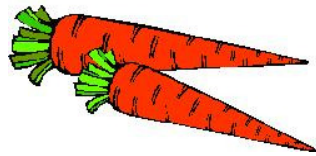
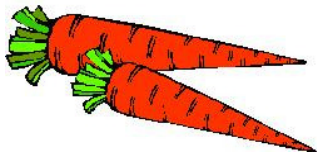


PEST MANAGEMENT IN THE FUTURE

A Strategic Plan for the Michigan Carrot Industry



Workshop Summary
March 12, 2007
Michigan State University
East Lansing, Michigan

Prepared by Dr. Mary K. Hausbeck
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PREVIOUS PMSP

A group of growers, processors and technical experts met in East Lansing, Michigan for one and a half days on March 1-2, 2000 to discuss the current problems encountered by the carrot industry. This meeting determined and summarized the critical needs of the Michigan carrot industry in terms of the efficacy of current pest management practices and tools and the feasibility of identified alternatives.

OUTCOMES

The industry priorities outlined by the 2000 Carrot Pest Management Strategic Plan were addressed in Michigan carrot research beginning in 2000. This research was supported by grant funding obtained from the USDA CSREES Risk Avoidance and Mitigation Program Awards Number 2004-51101-02207 (2004-06) and 00-51101-9594 (2000-05) and MSU GREEN Project GR00-056 (2000-03). Priorities that were listed in the 2000 but not in the 2007 PMSP include the following:

Research:

1. Identify effective reduced-risk fungicides and/or biocontrol agents and develop disease predictors to manage foliar blights.

Reduced risk and alternative products were tested for efficacy in yearly fungicide trials. Pyraclostrobin, a new fungicide, and reduced-risk products, azoxystrobin, boscalid, boscalid + pyraclostrobin effectively reduced foliar blights, giving growers alternatives to standard B2 carcinogenic products. Polyoxin D zinc salt, a biopesticide, alternated with chlorothalonil controlled foliar blight. Azoxystrobin alternated with chlorothalonil effectively limited foliar blights in all trials; pyraclostrobin alternated with chlorothalonil or copper and azoxystrobin alternated with mancozeb were also effective.

2. Develop effective methods to manage and determine the infectivity of aster leafhoppers.

An insecticide trial using the aster yellows index controlled the disease with 2 sprays of esfenvalerate using initial leafhopper infectivity and 1 spray of zeta-cypermethrin (OP alternative) using current leafhopper infectivity, as effectively as 5 weekly sprays of esfenvalerate. Aster yellows index treatment thresholds for Michigan growers are being determined weekly during the growing season since 2005. MSU Diagnostics Services tested aster leafhoppers for % infectivity to determine insecticide treatment thresholds which were disseminated in person and published in MSU Vegetable CATALerts, a growers' newsletter.

3. Identify carrot varieties suitable for Michigan that are resistant to nematodes, plant diseases and insects.

Yearly trials tested carrot cultivars for foliar blight susceptibility. Commercial cultivars Carson, Bolero, Canada, and Goliath showed foliar blight resistance.

Other Research Results:

Fungicide application technology was researched by using reduced and labeled rates of fungicides applied by flat or twin fans at 100 and 50 psi, respectively; all treatments had significantly healthier plants than the controls with reduced foliar infection and petiole disease

severity. Precision fungicide testing recommended flat fan or twin fan nozzles (effective at the lower psi that growers use); air-assisted nozzles did not provide good coverage.

The Tom-Cast disease forecaster reduced sprays while producing a quality crop in Michigan trials. The TOM-CAST forecaster was also tested for foliar blight control using satellite or on-site weather data; both programs significantly reduced disease compared to the untreated.

Nutrient trials studied the effects of nitrogen (N), phosphorous (P), and potassium (K) fertilization. Carrot yield and sugar content were increased when 30 lb N/A was topdressed 5 or 9 weeks after seeding. Topdressing at both 5 and 9 weeks increased yield and sugar content further. Applying up to 150 lb of P₂O₅ increased carrot biomass in low-medium-P soils; applying 75 lb K₂O maximized yield in low-K soils.

Herbicide trials tested pre and post treatments for efficacy on muck and sandy soils. Effective pre treatments for sand were 0.5 lb ai/A linuron, 0.5 lb clomazone, 1.7 lb s-metolachlor (reduced risk), 2 lb pendimethalin, 1 lb prometryn. Pre treatments for muck were 1 lb linuron, 2 lb pendimethalin, 1 lb prometryn. Effective post treatments for sand were 0.5 lb linuron, 0.125 lb oxyfluorfen, 0.063 lb flumioxazin, 1 lb prometryn on sand. Post treatments for muck were 0.25 or 0.5 lb linuron + 0.19 lb sethoxydim + crop oil concentrate, 0.25 lb metribuzin, 0.5 lb metribuzin. Oxyfluorfen, ethofumesate and prometryn performed well in yearly pre- and postemergence herbicide trials in commercial and research carrot fields. Metolachlor (reduced-risk) is now registered for preemergence use on carrot; oxyfluorfen is being registered through IR-4. Pendimethalin, ethofumesate and prometryn have received tolerances; prometryn should be registered soon and the others may be registered in the future.

First reports of *Phytophthora* spp. (rubbery brown root rot) on Michigan field carrots and *Alternaria radicina* (black rot) on Michigan field and stored carrots occurred in fall 2005.

Research results were disseminated yearly at growers' on-farm research and demonstration plots, journal articles and publications in the popular press and extension newsletters and growers' meetings, including the Great Lakes Fruit, Vegetable and Farm Market Expo held yearly in Grand Rapids, MI.

Regulatory:

- **Need registration of Dual and Select as alternatives for Lorox and Fusilade for weed control in commercial production.** Dual Magnum and Select are currently registered for use on carrots in Michigan.
- **The broad spectrum fungicide Bravo is essential to alternate with other site-specific pipeline fungicides for foliar disease resistance management.** Chlorothalonil (Bravo, Equus, Echo) is currently registered for use on carrots in Michigan.

WORKSHOP PARTICIPANTS

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TOP PRIORITIES OF MICHIGAN CARROT PRODUCTION

RESEARCH PRIORITIES:

- Identify factors that contribute to reduced yields and culls, with an emphasis on *Pythium* and *Phytophthora* spp., and nematodes.
- Identify in-furrow treatments, seed treatments for the control of *Pythium* and *Phytophthora* spp., insects, and nematodes.
- Develop effective control management for Powell amaranth, yellow nutsedge, marestail, mayweed, nightshade, dodder, jimson weed, wild carrot, and carrot seeders (bolters).
- Develop nitrogen-testing tools to meet new processor regulations.
- Develop improved facilities and disease management strategies for storing fresh market and processing carrots.

SECONDARY AREAS OF CONCERN FOR RESEARCH:

- Develop precision agriculture techniques for nitrogen applications.
- Understand how wild carrot and other plants act as a reservoir for aster yellows.
- Determine which cover cropping practices contribute to improved crop health and pest control characteristics in carrot production.

REGULATORY:

The following pesticides are critical for pest management and uses must be retained until safe, cost effective alternatives become available:

- Lorox and Fusilade are essential for weed control in commercial production; need Prowl as an alternative.
- The broad spectrum fungicide, mancozeb, is essential to alternate with other site-specific pipeline fungicides for foliar disease resistance management.
- Vydate, Vapam and the Telones are essential for nematode control.
- Submit new IR-4 weed control projects.
- Obtain mancozeb label.
- Partner with IR-4 to speed registration for in-furrow and seed treatments.
- Speed registration for Caparol.
- Obtain labels for herbicides through the IR-4 process (Nortron, Goal Tender, Command 3ME, Roundup wiper).

EDUCATIONAL:

- Promote on-farm diagnostic tests for soilborne carrot pests.
- Educate and provide technical support to growers and consultants as new technologies, strategies, and products are developed.
- Provide IPM education and on-farm demonstration plots (soil quality, cover crops, pesticide trials, food safety issues, etc.)
- Educate consumers on recent strides in IPM and production practices.
- Use weather tracking in aid of tracking of aster leafhoppers.
- Increase grower knowledge of seedborne pathogens.

EXECUTIVE SUMMARY

The purpose of this meeting was to update the Pest Management Strategic Plan (PMSP) developed from an initial meeting of the Michigan carrot industry representatives, researchers, and other stakeholders on March 1-2, 2000. This follow-up meeting provided an opportunity for the industry to redefine their priorities in light of recent research advances and the new challenges growers face. The meeting was attended by industry (5 growers), Michigan State University and Cornell University (16 research/university faculty and staff), the chemical industry (5 representatives) and officials from the state and federal governments (3 attendees).

Researchers had the opportunity to highlight new information from studies conducted since the last meeting. Growers discussed areas of concern, emerging problems, and ways to improve current practices. This workshop reevaluated problems identified at the 2000 PMSP meeting and new priorities were outlined.

The top priorities identified during the 2007 PMSP Workshop included the following : 1) Identify factors that contribute to reduced yields and culls, with an emphasis on *Pythium* and *Phytophthora* spp., and nematodes; 2) Identify in-furrow treatments, seed treatments for the control of *Pythium* and *Phytophthora* spp. insects, and nematodes; 3) Develop effective control management for Powell amaranth, yellow nutsedge, maretail, mayweed, nightshade, dodder, jimson weed, wild carrot, and carrot seeders (bolters); 4) Develop nitrogen-testing tools to meet new processor regulations; 5) Develop improved facilities and disease management strategies for storing fresh market and processing carrots.

New active ingredients have been added to the updated plan to reflect industry advances and include 1,3-dichloropropene, 1,3-dichloropropene/chloropicrin, azadirachtin, *Bacillus pumilus*, *Bacillus subtilis*, *Bacillus thuringensis*, *Beauveria bassiana*, chloropicrin, copper (metallic), deltamethrin, garlic juice extracts, harpin protein, metaldehyde, metam sodium, mono- and dipotassium salts of phosphorous acid, oxyfluorfen, oxyfluorfen/glyphosate, paraquat dichloride, pelargonic acid, metam potassium, potassium salts of fatty acids, pyrethrin, quizalofop, and *Streptomyces griseoviridis*.

BACKGROUND

Michigan ranks second nationally after California in fresh market carrot production (2,500 acres, valued at \$14.4 million) and fourth nationally in the production of carrots for processing (1,700 acres, valued at \$2.9 million). Carrot production in Michigan is located primarily in the west central region in the sandy loam soils of Montcalm, Mason, and Oceana Counties. Significant production of carrots for the fresh market also occurs in Newaygo and Lapeer Counties, where muck soils are common.

Michigan growers currently rely on herbicides, fungicides, and insecticides for pest management in carrot production. In most muck and some mineral soils, nematicides also play a critical role. Included among commonly used pesticides are organophosphates, carbamates and carcinogenic pesticides, which currently face an uncertain future as a result of the Food Quality Protection Act (FQPA). A segment of the industry already has the challenge of producing carrots for baby food without certain pesticides. Baby food processors are very conscious about residues and the impact they may have on the image of their product. In order to reduce or possibly eliminate the use of certain pesticides in the production of crops used in their products, baby food processors offer contracts to growers based on strict specifications regarding the use of pesticides. Following are the pests that are significant in Michigan carrot production.

Because high humidity and frequent rainfall or irrigation is common during the growing season, yield-threatening foliar blights are a recurring problem. Each year, foliar blights caused by fungi (*Alternaria dauci*, *Cercospora carotae*) and/or bacteria (*Xanthomonas campestris* pv. *carotae*) reduce photosynthetic area and weaken leaves and petioles. Michigan growers harvest carrots mechanically and weakened foliage can disrupt harvest due to carrot tops breaking off during lifting. In situations where foliar disease is severe and not controlled, the tops may be compromised to the extent that the crop cannot be harvested. Therefore, fungicides currently play a critical role in the management of foliar diseases.

Damaged, diseased or otherwise unmarketable carrots are known as culls. Approximately 30% of the carrots delivered to packing plants are rejected as not suitable (cull) for fresh market packs. Forking and stubbing of carrot roots is a complex problem likely resulting from a combination of mechanical damage, disease, and/or nematodes. Fungal diseases such as black root rot (*Chalara elegans*), black rot (*Alternaria radicina*), cavity spot (*Pythium* spp.), crater rot (*Rhizoctonia carotae*), crown rot (*Rhizoctonia solani*), Fusarium dry rot (*Fusarium* spp.), Phytophthora root rot (*Phytophthora cactorum*) and sour rot (*Geotrichum candidum*) affect root quality and reduce yield. Northern root knot (*Meloidogyne hapla*), carrot cyst (*Heterodera carotae*), pin (*Paratylenchus* sp.) and root lesion (*Pratylenchus penetrans*) nematodes are key pests of Michigan carrots grown in muck and some mineral soils causing galls, forked roots, overall disfiguration and stunting. The host range of root knot and root lesion nematodes is fairly large, while the carrot cyst nematode host range consists of carrots and closely-related species. Opportunities to rotate crops away from nematode-infested fields are limited for some growers. Aside from avoiding infested fields, soil fumigation has often been the best and only defense against serious soilborne pest infestations.

Aster yellows disease, caused by a phytoplasma transmitted by aster leafhoppers (*Macrostelus quadrilineatus*), results in distorted growth and fibrous, bitter-tasting roots. Aster leafhoppers acquire the phytoplasma locally from infected wild or cultivated carrots, or infective leafhoppers may be blown in on storm fronts coming from the southwest. Since aster leafhoppers can remain infective for 100 days, the disease is managed by applying insecticide sprays

depending on leafhopper numbers, cultivar resistance, and the presumed proportion of infective insects. Treatment thresholds are difficult to develop because the infectivity rate of aster leafhoppers can vary among years and locations. The efficacy of the preferred pyrethroid insecticides is compromised at high temperatures when control is most needed.

Insects that are occasionally a problem on carrots in Michigan include carrot weevils (*Listronotus oregonensis*), cutworms (Noctuidae), and green peach aphids (*Myzus persicae*). Adult carrot weevils feed on and lay eggs in leaf petioles while their larvae tunnel in the outer surface of the root, reducing root quality and making the root more vulnerable to soilborne pathogens. Cutworms can cause severe petiole damage and defoliation by their feeding habits. Green peach aphids suck plant sap, causing twisting and distortion of new growth, as well as potentially transmitting over 50 plant viruses. Control of these insects is accomplished primarily through weed management and the application of insecticides after scouting.

Using current cultural practices, it would be very difficult to produce carrots profitably without the use of herbicides. In order to prevent erosion and seedling injury, serious problems for many growers, cover crops such as rye are seeded along with the carrot crop. The cover crop is allowed to grow until it is four inches tall, at which time an herbicide is used to halt its competition with the carrot plants. Carrot seedlings emerge slowly and are weak, making them very susceptible to weed competition for the first six weeks of growth. Weeds compete for resources, act as hosts to insects and diseases, and cause mechanical problems with harvesting machinery. Since it is recommended that mechanical weed control only be used once carrots are 6-10 inches tall to avoid root injury, and that any movement of equipment across the field may negatively impact root development, quality and yield, the most commonly used method of weed control is with pre- and postemergence herbicides.

The impact ratings for the majority of carrot pest management tools on natural enemies of pests are unknown; however, those which are known are summarized here. Pest management tools are evaluated for acute and residual toxicity to parasitoids, predators and predator mites, and whether this toxicity would be lowered depending on timing of pesticide sprays, etc. *Bacillus thuringensis* (XenTari, Biobit HP, DiPel DF, DiPel ES, Javelin WG) is rated low in toxicity for all categories. Carbaryl (Sevin), endosulfan (Thionex), and methomyl (Lannate) are rated high in toxicity for all categories. Diazinon is rated medium-high for acute toxicity to parasitoids/predator mites and for residual toxicity to predators; medium for acute toxicity to predators and for residual toxicity to parasitoids/predator mites. Imidacloprid (Admire, Montana, Nuprid) is rated medium-high for acute toxicity to predators; low-medium for acute toxicity to parasitoids; and low for acute toxicity to predator mites and for residual toxicity to parasitoids/predators/predator mites. Malathion is rated high for parasitoid/predator acute toxicity; medium-high for parasitoids/predators residual toxicity; and medium for predator mites acute and residual toxicities. Pyrethrins (Bug Buster-O) are rated medium-high for acute toxicity to parasitoids/predators; medium for acute toxicity to predator mites; low-medium for residual toxicity to parasitoids; and low for residual toxicity to predators/predator mites. Sulfur (Kumulus DF, Microthiol Disperss, Micro Sulf, Thiolum Jet, Yellow Jacket) is rated medium for parasitoid acute toxicity; low-high for predator mites acute toxicity; low-medium for predator acute toxicity and predator mites residual toxicity; and low for parasitoids/predators residual toxicity; also timing of the spray can lower these impacts. Timing of the spray does not lower the impact of the other pest management tools summarized previously in this paragraph.

OUTLINE OF PLAN

The remainder of this document is a pest by pest analysis of the current role of organophosphates (OPs), carbamates and pesticides classified as B2 carcinogens, reduced risk pesticides and biopesticides by the Environmental Protection Agency (EPA) and /or the IR-4 Project. Other pest management aids (chemical, cultural and otherwise) that offer some control but are not “stand alone” tools, pipeline pest management tools (identified as effective but not yet available), and “to do” lists for research, regulatory, and educational needs are listed. Pests are presented in alphabetical order.

DISEASE PATHOGENS

1. **ASTER YELLOWS** - See aster leafhopper.

2. **BACTERIAL LEAF BLIGHT (*Xanthomonas campestris* pv. *carotae*)**

Not endemic to area but may be introduced via seed. Yellow-ringed dark blighting on leaves and roots first appear on the lower side of the leaf, then dark streaks may form on the petioles accompanied by a sticky, yellow exudate.

B2 carcinogenic bactericides currently registered:

- None identified.

Other bactericides currently registered:

- *Bacillus subtilis* QST 713 strain (Rhapsody, Serenade ASO, Serenade MAX): Efficacy – poor. Classified as a biopesticide.

Other pest management aids:

- Copper hydroxide (Champ DP Dry Prill, Champ Formula 2F, Champion WP, Kocide 101, Kocide 4.5FL, Kocide 2000, Kocide DF, Nu-Cop 3L, Nu-Cop 50DF, Nu-Cop HB): Efficacy – fair to poor. These products are currently not labeled to control bacterial leaf blight on carrot; however, they are labeled for use on other *Xanthomonas*.
- *Xanthomonas*-indexed seed.
- Scouting.
- Postharvest tilling to aid breakdown of infected plant debris.
- Crop rotation (minimum 2 years).
- Cultivar tolerance, if any.

Pipeline pest management tools:

- Enhanced seed testing and treatment.
- Rapid laboratory and on-farm diagnostic tests.

“To do” list for bacterial blight:

Research needs:

- Identify more effective seed treatments.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

3. BLACK ROOT ROT (*Chalara elegans*)

Black root rot is generally considered a postharvest pathogen but it can also infect seedlings and mature carrots under high humidity and temperatures above 75°F. Infected carrots develop black lesions on the surface and in cracks and wounds. Survival structures can remain in the soil for years. The pathogen develops rapidly on wounded carrots that have been washed, graded, packed and stored at temperatures above 77°F and high relative humidity.

B2 carcinogenic fungicides currently registered:

- None identified.

Other fungicides currently registered:

- None identified.

Other pest management aids:

- Rotate with nonhost crops.
- Careful harvest handling.
- Storing carrots in proper environmental conditions.
- Dipping carrots in chlorinated, hydrocooled water can minimize disease development.

Pipeline pest management tools:

- None identified.

“To do” list for black root rot:

Research needs:

- None identified.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

4. BLACK ROT (*Alternaria radicina*)

Older senescing petioles on mature plants are particularly susceptible and provide an avenue for infection of the carrot crown, which appears as a black ring of decay where the petioles attach to the root. Carrots infected later in the growing season may not develop visible lesions until after harvest. Disease development is favored by high relative humidity (>92%) and warm storage conditions. Symptoms on stored carrots appear as dry, black, sunken lesions which can decay the entire root and spread to adjacent carrots.

B2 carcinogenic fungicides currently registered:

- Iprodione (Iprodione 4L AG, Rovral 75WG): Efficacy – good.

Other fungicides currently registered:

- *Bacillus subtilis* QST 713 strain (Rhapsody, Serenade ASO, Serenade MAX): Efficacy – poor. Classified as a biopesticide.

Other pest management aids:

- Rotate with nonhost crops.

Pipeline pest management tools:

- None identified.

“To do” list for black root rot:

Research needs:

- Identify storage conditions that limit disease development.

Regulatory needs:

- None identified.

Educational needs:

- Provide resources to growers and processors with helpful storage guidelines.

5. CAVITY SPOT (*Pythium* spp.)

A fungal disease that causes elliptical sunken lesions on roots that darken and increase in size with age, which can reduce overall marketable yields.

B2 carcinogenic fungicides currently registered:

- 1,3-Dichloropropene (Telone II): Efficacy – good. Fumigant.
- 1,3-Dichloropropene/chloropicrin (Pic-Clor 60, Telone C-17, Telone C-35): Efficacy – good. Fumigant.
- Mefenoxam/chlorothalonil (Ridomil Gold/Bravo): Efficacy – good. Not typically used.
- Metam potassium (K-Pam HL, Metam KLR54, Sectagon-K54): Efficacy – good. Fumigant. Also classified as a carbamate.
- Metam sodium (Vapam HL): Efficacy – good. Fumigant. Also classified as a carbamate.

Other fungicides currently registered:

- Chloropicrin (Chloropicrin, NutraPic Fumigant): Efficacy – unknown. Fumigant.
- Mefenoxam/copper hydroxide (Ridomil Gold/Copper): Efficacy – fair. Not typically used.
- Mefenoxam (Apron XL LS, Ridomil Gold EC, Ridomil Gold SL, Ultra Flourish): Efficacy – fair to good. Applied at planting. Used in heavily infested fields. Limited time of control. Classified as a reduced-risk fungicide.
- Metalaxyl (MetaStar 2E AG): Efficacy – good. Classified as a reduced-risk fungicide.

Other pest management aids:

- Crop rotation (minimum of 3-4 years) with nonsusceptible crops.
- Sanitation, including washing machinery and equipment between fields.

Pipeline pest management tools:

- None identified.

“To do” list for cavity spot:

Research needs:

- Phosphate applications such as Phostrol and Aliette.
- Identify tolerant cultivars, if any exist.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

6. CRATER ROT (*Rhizoctonia carotae*)

Symptoms are not evident when harvested, but usually take two to three months to develop in storage. Small craters develop under small white hyphal knots on the root surface and enlarge rapidly to become dry, sunken lesions lined with white cottony mycelium. This is also an increasing problem in other states, including New York.

B2 carcinogenic fungicides currently registered:

- 1,3-Dichloropropene (Telone II): Efficacy – good. Fumigant.
- 1,3-Dichloropropene/chloropicrin (Pic-Clor 60, Telone C-17, Telone C-35): Efficacy – good. Fumigant.
- Metam potassium (K-Pam HL, Metam KLR54, Sectagon-K54): Efficacy – unknown. Fumigant. Also classified as a carbamate.
- Metam sodium (Vapam HL): Efficacy – unknown. Fumigant. Also classified as a carbamate.

Chemical control currently registered:

- None identified.

Other pest management aids:

- Sanitation, including washing machinery and equipment between fields.
- Care in harvesting to avoid cuts and bruises.
- Sanitary storage facilities, containers and handling equipment.
- Proper management of temperature (32°F), relative humidity (<95%), and air circulation in storage facilities.
- Extended (>3 years) crop rotation with nonsusceptible crops.

Pipeline pest management tools:

- None identified.

“To do” list for crater rot:

Research needs:

- Effective materials screening. Strobilurin in-furrow.
- Application of materials.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

7. CROWN ROT (*Rhizoctonia solani*)

This pathogen typically infects roots as they approach maturity, but it can cause damping-off of carrot seedlings. Field symptoms include premature senescence and death of foliage. On carrot roots, symptoms include dark brown sunken lesions or cankers near the crown or on other parts of the root. This is usually a dry rot, but occasional invasion by soil bacteria and other fungi may induce soft rot. This pathogen overwinters as mycelia and sclerotia and can cause infection anytime during the growing season under high moisture and temperatures >64°F. *Rhizoctonia solani* can spread from plant to plant in closely spaced carrots when the canopy is fully formed and from root to root in storage.

B2 carcinogenic fungicides currently registered:

- 1,3-Dichloropropene (Telone II): Efficacy – good. Fumigant.

- 1,3-Dichloropropene/chloropicrin (Pic-Clor 60, Telone C-17, Telone C-35): Efficacy – good. Fumigant.
- Metam potassium (K-Pam HL, Metam KLR54, Sectagon-K54): Efficacy – unknown. Fumigant. Also classified as a carbamate.
- Metam sodium (Vapam HL): Efficacy – unknown. Fumigant. Also classified as a carbamate.

Other fungicides currently registered:

- None identified.

Other pest management aids:

- Rotate with small grains to reduce inoculum levels.

Pipeline pest management tools:

- None identified.

“To do” list for crown rot:

Research needs:

- None identified.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

8. DAMPING-OFF (*Pythium* spp., *Rhizoctonia solani*); ROOT FORKING, STUBBING (*Pythium* spp., *Phytophthora* spp.); ROOT DIEBACK (*Pythium* spp.)

Diseases caused by several fungi. Damping-off occurs when infected seedlings wilt, turn brown and die, or develop a water-soaked, discolored stem at the ground level and topple over, resulting in poor stands. Deformation of roots (forking, stubbing) reduces yields.

B2 carcinogenic pesticides currently registered:

- 1,3-Dichloropropene (Telone II): Efficacy – good. Fumigant.
- 1,3-Dichloropropene/chloropicrin (Pic-Clor 60, Telone C-17, Telone C-35): Efficacy – good. Fumigant.
- Metam potassium (K-Pam HL, Metam KLR54, Sectagon-K54): Efficacy – unknown. Fumigant. Also classified as a carbamate.
- Metam sodium (Vapam HL): Efficacy – good. Fumigant. Also classified as a carbamate.

Other pesticides currently registered:

- Chloropicrin (Chloropicrin, NutraPic Fumigant): Efficacy – unknown. Fumigant.
- Fludioxonil (Maxim 4FS): Efficacy – fair. Seed treatment. Classified as a reduced-risk pesticide.
- Mefenoxam (Apron XL LS, Ridomil Gold EC, Ridomil Gold SL, Ultra Flourish) Efficacy – fair. Classified as a reduced-risk pesticide. Seed treatment, in-furrow treatment.
- Metalaxyl (Allegiance-FL, MetaStar 2E AG) Efficacy – good on *Pythium*. Seed treatment. Classified as a reduced-risk pesticide.
- Mono- and dipotassium salts of phosphorous acid (Fosphite, Topaz): Efficacy – poor. Classified as a biopesticide.

- Thiram (Thiram 42S, Thiram 50WP Dyed) Efficacy – fair. Seed treatment.

Other pest management aids:

- Good soil drainage.
- Crop rotation with nonsusceptible crops (>3 years).
- Irrigate with clean water source.

Pipeline pest management tools:

- None identified.

“To do” list for damping off/root forking, stubbing:

Research needs:

- Identify pathogen incidence in various water sources.
- Determine how irrigation practices aid in the spread of this disease.
- Identify weather conditions that favor disease development.
- Look at other new oomycete materials for control.

Regulatory needs:

- None identified.

Educational needs:

- Proper irrigation tactics and techniques.

9. FUNGAL LEAF SPOTS/BLIGHT (*Alternaria dauci*, *Cercospora carotae*)

Symptoms of *Alternaria* leaf spot include dark brown/black spots with yellow margins appearing on older leaves. Severe disease results in weak petioles or defoliation, thereby making harvest difficult. Symptoms of *Cercospora* leaf spot include small circular brown spots which rapidly enlarge, accompanied by yellow/red discoloration on younger leaves and girdled petioles, resulting in defoliation. The two pathogens often occur together and are managed similarly.

B2 carcinogenic fungicides currently registered:

- Azoxystrobin/chlorothalonil (Quadris Opti): Efficacy – excellent.
- Chlorothalonil (Applause 720, Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Echo 75WDG, Echo 90DF, Echo 720, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF): Efficacy – good. Field application only. High importance, commonly used, cost effective.
- Iprodione (Iprodione 4HL AG, Rovral 4F): Efficacy – good. Field application and seed treatment. Expensive, but is often used, especially when disease is well established. Systemic, residue may be detected in finished product.

Other fungicides currently registered:

- Azoxystrobin (Amistar, Quadris F): Efficacy – good to excellent. Classified as a reduced-risk pesticide.
- Boscalid (): Efficacy – good to excellent. Classified as a reduced-risk pesticide.
- Copper hydroxide (Champ DP Dry Prill, Champ Formula 2F, Champion WP, Kocide 101, Kocide 4.5FL, Kocide 2000, Kocide 3000, Kocide DF, Nu-Cop 3L, Nu-Cop 50DF, Nu-Cop HB): Efficacy – fair to poor. Currently, copper-based fungicides alone do not control disease at a commercially acceptable level when pressure is significant.
- Copper, metallic (Copper-Count-N): Efficacy – poor. Currently, copper-based fungicides alone do not control disease at a commercially acceptable level when

pressure is significant.

- Copper oxide (Nordox 75WG): Efficacy – fair to poor. Currently, copper-based fungicides alone do not control disease at a commercially acceptable level when pressure is significant.
- Copper oxychloride (COC DF): Efficacy – fair to poor. Currently, copper-based fungicides alone do not control disease at a commercially acceptable level when pressure is significant.
- Copper oxychloride sulfate (C-O-C-S WDG): Efficacy – fair to poor. Currently, copper-based fungicides alone do not control disease at a commercially acceptable level when pressure is significant.
- Copper resinate (Tenn-Cop 5E): Efficacy – poor. Currently, copper-based fungicides alone do not control disease at a commercially acceptable level when pressure is significant.
- Copper sulfate (Basicop, Basic Copper, Cuprofix Ultra 40 Disperss): Efficacy – poor. Currently, copper-based fungicides alone do not control disease at a commercially acceptable level when pressure is significant.
- Cyprodinil/fludioxonil (Switch 62.5WG): Efficacy – good on *Alternaria* and poor on *Cercospora*. Classified as a reduced-risk pesticide.
- Neem oil (Trilogy): Efficacy – poor. Classified as a biopesticide.
- Pyraclostrobin (Cabrio EG): Efficacy – excellent.
- Pyraclostrobin/boscalid (Pristine): Efficacy – excellent. Classified as a reduced-risk pesticide.
- Trifloxystrobin (Flint): Efficacy – excellent. Classified as a reduced-risk-pesticide.

Other pest management aids:

- Certified, tested and treated seed.
- Scouting.
- Postharvest tilling to speed breakdown of infected plant debris.
- Crop rotation with nonsusceptible crops (minimum of 2 years).
- Planting disease-tolerant cultivars suitable for Michigan and targeted markets.
- Use of a disease forecasting program to time fungicide sprays.

Pipeline pest management tools:

- Cyprodinil (Vanguard): Efficacy – good to excellent for *Alternaria*, poor for *Cercospora*. Classified as a reduced-risk pesticide.
- Fenbuconazole (Indar): Efficacy – excellent on *Alternaria* and poor to fair for *Cercospora*. Classified as a C carcinogen.
- Kresoxim-methyl (Sovran): Efficacy – excellent.
- Mancozeb (Penncozeb): Efficacy – good. Classified as a B2 carcinogen.
- Tebuconazole (Folicur): Efficacy – poor to fair. Classified as a C carcinogen.
- Trifloxystrobin/propiconazole (Stratego): Efficacy – good to excellent. Trifloxystrobin classified as a reduced-risk fungicide; propiconazole classified as a C carcinogen.

“To do” list for fungal leaf spots/blight:

Research needs:

- Continue cultivar screens to identify tolerant varieties.
- Weather data collection from different sources to predict foliar blights.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

10. FUSARIUM DRY ROT (*Fusarium* spp.)

Symptoms of the disease include brown, leathery lesions, side cankers and crown decay. Disease is severe on carrots held in fields after maturity. This pathogen has been found in multiple sites in Michigan but is considered a minor issue.

B2 carcinogenic fungicides currently registered:

- 1,3-Dichloropropene (Telone II): Efficacy – good. Fumigant.
- 1,3-Dichloropropene/chloropicrin (Pic-Clor 60, Telone C-17, Telone C-35): Efficacy – good.

Other fungicides currently registered:

- Chloropicrin (Chloropicrin, NutraPic Fumigant): Efficacy – unknown. Fumigant.

Other pest management aids:

- None identified.

Pipeline pest management tools:

- None identified.

“To do” list for Fusarium dry rot:

Research needs:

- None identified.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

11. GRAY MOLD (*Botrytis* spp.)

Gray mold is primarily a storage problem. Not considered a typical problem in the field.

B2 carcinogenic fungicides currently registered:

- None identified.

Other fungicides currently registered:

- *Bacillus subtilis* QST 713 strain (Serenade ASO): Efficacy – poor. Classified as a biopesticide.
- Thiabendazole (Mertect 340-F Dip): Efficacy – fair.

Other pest management aids:

- Scouting.
- Plant in well-drained soils.
- Remove and destroy infected plant debris.
- Minimum 3 year crop rotation with nonsusceptible crops (avoid beans, cucurbits and cabbage).

Pipeline pest management tools:

- None identified.

“To do” list for gray mold:

Research needs:

- None identified.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

12. PHYTOPHTHORA ROOT ROT/RUBBERY BROWN ROT (*Phytophthora cactorum*)

Symptoms include dark brown to black, water-soaked lesions and a rubbery consistency of the root. Lesions occur in one or more bands anywhere on the carrot root. White mycelia may be present on lesions, which facilitates the spread of the fungus.

B2 carcinogenic fungicides currently registered:

- 1,3-Dichloropropene (Telone II): Efficacy – good. Fumigant.
- 1,3-Dichloropropene/chloropicrin (Pic-Clor 60, Telone C-17, Telone C-35): Efficacy – good. Fumigant.
- Metam sodium (Vapam HL): Efficacy – unknown. Fumigant. Also classified as a carbamate.
- Metam potassium (K-Pam HL, Metam KLR54, Sectagon-K54): Efficacy – unknown. Fumigant. Also classified as a carbamate.

Other fungicides currently registered:

- Chloropicrin (Chloropicrin, NutraPic Fumigant): Efficacy – unknown. Fumigant.

Other pest management aids:

- None identified.

Pipeline pest management tools:

- None identified.

“To do” list for Phytophthora root rot:

Research needs:

- None identified.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

13. POWDERY MILDEW (*Erysiphe polygoni*)

Not considered a significant problem. Sporadic occurrences found later in season.

B2 carcinogenic fungicides currently registered:

- None identified.

Other fungicides currently registered:

- *Bacillus pumilus* QST 2808 strain (Sonata Biofungicide): Efficacy – poor. Classified as a biopesticide.
- *Bacillus subtilis* QST 713 strain (Serenade ASO, Serenade MAX): Efficacy – poor. Classified as a biopesticide.
- Neem oil (Trilogy): Efficacy – poor. Classified as a biopesticide.
- Pyraclostrobin (Cabrio EG): Efficacy – good.

- Pyraclostrobin/boscalid (Pristine): Efficacy – excellent. Classified as a reduced-risk fungicide.
- Sulfur (Kumulus DF, Microthiol Disperss, Micro Sulf, Sulfur 6L, Sulfur DF, Thiolux Jet, Yellow Jacket): Efficacy – fair.
- Trifloxystrobin (Flint): Efficacy – good. Classified as a reduced-risk fungicide.

Other pest management aids:

- Scouting.

Pipeline pest management tools:

- None identified.

“To do” list for powdery mildew:

Research needs:

- None identified.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

14. SOUR ROT (*Geotrichum candidum*)

A fungal disease that infects carrots through wounds. Soft, watery, colorless decay develops on roots. Infection first occurs in the field and can continue during storage. It has been found in storage almost every year, more common in larger carrots.

B2 carcinogenic fungicides currently registered:

- None identified.

Other fungicides currently registered:

- None identified.

Other pest management aids:

- None identified.

Pipeline pest management tools:

- None identified.

“To do” list for sour rot:

Research needs:

- None identified.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

15. WHITE MOLD (*Sclerotinia sclerotiorum*)

White mold is primarily a storage problem. Not considered a typical problem in the field. It can become a problem when susceptible crops are used in the rotation.

B2 carcinogenic fungicides currently registered:

- 1,3-Dichloropropene (Telone II): Efficacy – good. Fumigant.
- 1,3-Dichloropropene/chloropicrin (Pic-Clor 60, Telone C-17, Telone C-35): Efficacy – good. Fumigant.
- Metam potassium (K-Pam HL, Metam KLR54, Sectagon-K54): Efficacy –

unknown. Fumigant. Also classified as a carbamate.

- Metam sodium (Vapam HL): Efficacy – unknown. Fumigant. Also classified as a carbamate.

Other fungicides currently registered:

- *Bacillus pumilus* QST 2808 strain (Sonata Biofungicide): Efficacy – poor. Classified as a biopesticide.
- *Bacillus subtilis* QST 713 strain (Serenade ASO, Serenade MAX): Efficacy – poor. Classified as a biopesticide.
- Thiabendazole (Mertect 340-F Dip): Efficacy – fair.

Other pest management aids:

- Scouting.
- Plant in well-drained soils.
- Remove and destroy infected plant debris.
- Minimum 3-year crop rotation with nonsusceptible crops (avoid beans, cucurbits and cabbage).

Pipeline pest management tools:

- *Coniothyrium minitans* (Contans): Efficacy – unknown. Classified as a biopesticide.

“To do” list for white mold:

Research needs:

- Storage treatments.
- Washing carrots.
- Application technology of materials.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

INSECTS

1. ASTER LEAFHOPPER (*Macrostelus quadrilineatus*)

Mobile vector of aster yellows, a serious disease of carrots for which there is no chemical control. Disease symptoms appear 10-20 days after transmission.

OP insecticides currently registered: Some processors restrict/prohibit their use; are also considered B2 carcinogens.

- Malathion (Malathion 8 Aquamul, Malathion 57EC): Efficacy – limited use. Used in rotation with other products for resistance management, although resistance is not a major concern with this product. Used from June to August; discontinued 3 weeks before harvest. Economic threshold depends on the percentage of leafhoppers carrying the pathogen and disease resistance of the carrot variety.

Carbamate insecticides currently registered: Some processors restrict/prohibit their use; are also considered B2 carcinogens.

- Carbaryl (10% Sevin Granuales, Carbaryl 4L, Sevin 4F, Sevin 80S, Sevin 80WSP, Sevin XLR Plus): Efficacy – good. Used in rotation with other products for

resistance management, although resistance is not a major concern with this product. Used from June to August; discontinued 3 weeks before harvest. Economic threshold depends on the percentage of leafhoppers carrying the pathogen and disease resistance of the carrot variety.

Other insecticides currently registered:

- Azadirachtin (Aza-Direct, Azatin XL, Azatrol EC, Ecozin 3%EC, Neemix 4.5): Efficacy – fair. Classified as a biopesticide.
- Cyfluthrin (Baythroid 2, Baythroid XL, Renounce 20WP, Tombstone, Tombstone Helios): Efficacy – excellent to good. Not widely used. Relatively expensive, about \$1.00 to \$1.50 more per acre than esfenvalerate, but more effective in hot weather.
- Deltamethrin (Battalion 0.2EC, Delta Gold): Efficacy – unknown.
- Endosulfan (Endosulfan 3EC, Thionex 3EC, Thionex 50W): Efficacy – good. Some processors restrict or prohibit use; not used much. Only one application allowed per season.
- Esfenvalerate (Asana XL, Adjourn, S-Fenvalo Star): Efficacy – excellent. High use, high importance. Not effective in hot weather (>85°F).
- Garlic juice extracts (Allityn): Efficacy – poor. Classified as a biopesticide.
- Imidacloprid (Admire Pro, Admire 2F, Advise 2FL, Alias 2F, Couraze 2F, Impulse 1.6FL, Macho 2.0FL, Montana 2F, Nuprid 1.6F, Nuprid 2F, Pasada 1.6F, Prey 1.6, Provado 1.6F, Torrent 2F, Widow): Efficacy – fair to good. Classified as a group E chemical and considered an OP alternative.
- Methomyl (Lannate LV, Lannate SP): Efficacy – limited use. Handler and applicator concerns. Cost is twice that of pyrethroids. Short residual. More effective than esfenvalerate in hot weather. Classified as a group E chemical.
- Potassium salts of fatty acids (M-Pede): Efficacy – poor. Classified as a biopesticide.
- Pyrethrin (PyGanic EC 1.4 II, Pyganic EC 5.0 II): Efficacy – fair.
- Thiamethoxam (Actara, Platinum): Efficacy – fair to good. Classified as a group C chemical.

Other pest management aids:

- Scouting.
- Tolerant cultivars.

Pipeline pest management tools:

- None identified.

“To do” list for aster leafhopper:

Research needs:

- Fine tune the PCR test, infectivity rates, and spray forecast.
- Understand the role wild carrot plays in spreading disease.
- Better understanding of how cultivar differences (color, etc.) contribute to tolerance to the pathogen.
- Determine the approximate time the first flight of insects will arrive and the importance of controlling them at this time.
- Determine if the potato leafhopper forecaster is applicable for aster leafhopper predictions.
- Investigate the possibility of regional predictions and a warning system.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

2. CARROT WEEVIL (*Listronotus oregonensis*)

Carrot weevils are occasionally a problem, especially in areas with limited or no crop rotation. Carrot weevils were first recognized as a problem in Michigan in 1999 when about 1% of the crop was damaged. Weevils mate in grassy areas at the edges of the fields and may move into carrots when populations are high. Pyrethroid applications that target other pests may be controlling the weevil.

OP insecticides currently registered: Also considered B2 carcinogens.

- Malathion (Malathion 57EC): Efficacy – good.

Carbamate insecticides currently registered: Also considered B2 carcinogens.

- Oxamyl (Vydate L): Efficacy – good. Registered for control of larvae. Application at planting may control a number of nontarget pests. Systemic activity with foliar uses also. Postplant application has a 24(c) registration.

Other insecticides currently registered:

- Azadirachtin (Aza-Direct, Azatin XL, Azatrol EC, Ecozin 3%EC, Neemix 4.5): Efficacy – poor. Classified as a biopesticide.
- Cyfluthrin (Baythroid 2, Baythroid XL, Renounce 20WP, Tombstone, Tombstone Helios): Efficacy – good. Registered for control of adult weevils. Applications targeting aster leafhoppers may be providing control.
- Esfenvalerate (Adjourn, Asana, S-Fenvalo Star): Efficacy – good. Registered for control of adult weevils. Applications targeting aster leafhoppers may be providing control. Classified as a group C chemical.
- Garlic juice extracts (Allityn): Efficacy – poor. Classified as a biopesticide.
- Pyrethrin (PyGanic EC 1.4 II, PyGanic EC 5.0 II): Efficacy – fair.

Other pest management aids:

- Scouting.
- Biological control of carrot weevils by *Anaphes sordidatus*, an egg parasitoid.
- Rotation with crops other than celery.
- Control of broadleaf weeds in field borders, especially wild carrot, pineapple weed, plantain and other alternate hosts for carrot weevil.
- Good sanitation via disposal of culls and trimmings.
- Trapping to determine pest density and timing of insecticide application.

Pipeline pest management tools:

- None identified.

“To do” list for carrot weevil:

Research needs:

- None identified.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

3. CUTWORMS (*Noctuidae*)

A sporadic pest, mostly a problem when a grass field is plowed down for carrot production.

OP insecticides currently registered: Also considered B2 carcinogens.

- Diazinon (Diazinon 14G, Diazinon 5W, Diazinon 50W, Diazinon AG500): Efficacy – good.

Carbamate insecticides currently registered: Also considered B2 carcinogens.

- Carbaryl (10% Sevin Granules, Carbaryl 4L, Sevin 4F, Sevin 80S, Sevin 80WSP, Sevin XLR Plus): Efficacy – good to excellent.

Other insecticides currently registered:

- Azadirachtin (Aza-Direct, Azatin XL, Azatrol EC, Ecozin 3%EC, Neemix 4.5): Efficacy – fair. Classified as a biopesticide.
- *Bacillus thuringiensis* subsp. *kurstaki* (Biobit HP, DiPel DF, DiPel ES, Javelin WG): Efficacy – fair to good. Classified as a biopesticide
- *Bacillus thuringiensis* subsp. *aizawai* (XenTari): Efficacy – fair to good. Classified as a biopesticide.
- Cyfluthrin (Baythroid 2, Baythroid XL, Renounce 20WP, Tombstone, Tombstone Helios) Efficacy – good to excellent. Tends to be more expensive than other chemicals.
- Deltamethrin (Battalion 0.2EC, Delta Gold): Efficacy – good.
- Methomyl (Lannate LV, Lannate SP): Efficacy – good to excellent. Tends to be expensive. If pest is detected early, need only be applied to field edges. Classified as a group E chemical.
- Esfenvalerate (Adjourn, Asana, S-Fenvalo Star): Efficacy – good to excellent. Commonly used by growers. Classified as a group E chemical.

Other pest management aids:

- Scouting.
- Keeping edges of fields weed-free.
- Delay planting after killing cover crop.

Pipeline pest management tools:

- None identified.

“To do” list for cutworms:

Research needs:

- None identified.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

4. GREEN PEACH APHID (*Myzus persicae*)

Green peach aphids are rarely a problem but may be seen in late season when hot and dry or as a result of treatment with carbamate and pyrethroid insecticides that kill natural predators. The sunflower aphid (*Aphis helianthi*) may also be involved. Both species may be highly resistant to many insecticides. Use of broad spectrum fungicides

(primarily EBDCs and chlorothalonil) may also increase aphid problems by destroying fungi which attack insects.

OP insecticides currently registered: Also considered B2 carcinogens.

- Malathion (Malathion 57EC, Malathion 8 Aquamul): Efficacy – fair to good.
- Diazinon (Diazinon 5W): Efficacy – good.

Carbamate insecticides currently registered: Also considered B2 carcinogens.

- None identified.

Other insecticides currently registered:

- Azadirachtin (Aza-Direct, Azatin XL, Azatrol EC, Ecozin 3%EC, Neemix 4.5): Efficacy – fair. Classified as a biopesticide.
- *Beauveria bassiana* strain GHA (BotaniGard ES): Efficacy – poor. Classified as a biopesticide.
- Deltamethrin (Battalion, Delta Gold): Efficacy – fair to good.
- Endosulfan (Endosulfan 3EC, Thionex 3EC, Thionex 50W): Efficacy – good.
- Imidacloprid (Admire Pro, Admire 2F, Advise 2FL, Alias 2F, Couraze 2F, Impulse 1.6FL, Macho 2.0FL, Montana 2F, Nuprid 1.6F, Nuprid 2F, Pasada 1.6F, Prey 1.6, Provado 1.6F, Torrent 2F, Widow): Efficacy – good. Classified as a group E chemical.
- Potassium salts of fatty acids (M-Pede): Efficacy – poor. Classified as a biopesticide.
- Pyrethrin (PyGanic EC 1.4II, PyGanic EC 5.0II): Efficacy – fair.

Other pest management aids:

- Scouting.
- Maintain natural enemy populations by judiciously using insecticides when controlling other pests.

Pipeline pest management tools:

- None identified.

“To do” list for green peach aphid:

Research needs:

- None identified.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

NEMATODES

Nematodes are a significant problem in Michigan’s muck soils, as well as in some mineral soils and are partly responsible for culls (unmarketable carrots). It is extremely important to protect carrots from nematodes for three weeks after germination.

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

Moderate host range and a very common problem in muck soils and is a major reason for the decline of carrot production. This nematode is significantly less of a problem in mineral soils because of the rotation system with nonhost crops.

2. CARROT CYST NEMATODE (*Heterodera carotae*)

Michigan is the only reported location of this species in the western hemisphere. A very common species throughout Michigan organic soils used for carrot production, but has never been detected in mineral soils in Michigan. It has a very narrow host range and is difficult to manage because it can persist in soil without a host for 10 years. This is a key reason for the decline of carrot production in organic soil in Michigan.

3. PENETRANS ROOT LESION NEMATODE (*Pratylenchus penetrans*)

A very wide host range and the most common plant-parasitic nematode in Michigan. Not a problem in most Michigan mineral soil carrot fields; however, a highly aggressive population exists in west central Michigan that causes extensive carrot losses.

4. PIN NEMATODE (*Paratylenchus* sp.)

A sporadic pest. Two species are known to exist in Michigan. *Paratylenchus projectus* exists mainly in mineral soil and *P. hamatus* in organic soil.

OP nematicides currently registered:

- None identified.

Carbamate nematicides currently registered: Carbamates are also considered B2 carcinogens.

- Metam potassium (K-Pam HL, Metam KLR54, Sectagon-K54): Efficacy – unknown. Fumigant.
- Metam sodium (Vapam HL): Efficacy – good. Fumigant. Applied as a chemigant (in irrigation water), environmental risks. Ground driven applicators often apply with too little water, do not get efficacy. Soil temperature requirements make it exceptionally well suited to Michigan's cold soils.
- Oxamyl (Vydate L): Efficacy – fair to good. Most effective when used in multiple applications at a low rate, not effective on carrot cyst nematode. Efficacy inconsistent among years and locations (no longer effective on some sites).

Other B2 carcinogenic nematicides currently registered:

- 1,3-Dichloropropene (Telone II): Efficacy – excellent in most situations. Requires specialized application equipment, higher rates required for carrot cyst nematode and use in organic soil. Must be applied when temperatures exceed 50°F. No longer effective on specific sites in Lapeer and Newaygo Counties. Expensive, compared to nonfumigant nematicides.
- 1,3-Dichloropropene/chloropicrin (Pic-Clor 60, Telone C-17, Telone C-35): Efficacy – unknown. Considered a partial methyl bromide alternative.

Other nematicides currently registered:

- Azadirachtin (Azatrol EC, Ecozin 3%EC): Efficacy – unknown. Classified as a biopesticide.
- Chloropicrin (Chloropicrin, NutraPic Fumigant): Efficacy – unknown.
- Harpin protein (N-Hibit): Efficacy – unknown. Classified as a biopesticide.

Other pest management aids:

- Crop rotation (minimum of 3-4 years) with nonhost crops such as corn, wheat, and rye (longer rotation required for carrot cyst nematode).
- Sanitation, including cleaning machinery and equipment between fields.
- Use of biofumigation methodology works when done properly.
- Use of trap crops.
- Soil quality enhancement with green manure crops (i.e., mustards, oilseed radish, sudax) or other soil amendments. Mustards and oilseed radish must be plowed down before green pod stage. Avoid legumes (clovers, alfalfa and vetch) unless the cover crop is to be established for two or more years.

Pipeline pest management tools:

- None identified.

“To do” list for nematodes:**Research needs:**

- Conduct more sampling across growing areas to determine population levels.
- Evaluate current threshold levels to determine applicability.
- Refine bioassay techniques for growers to use in Michigan.

Regulatory needs:

- Protect registration.
- Add comments to federal registry.

Educational needs:

- Comprehensive grower, MSU Extension Educator and consultant training in nematode diagnostics.
- Bioassay training for growers, MSU extension and consultants.
- Threshold levels from MSU Diagnostic Services. Do they match different populations in state?
- Research on the biology and management of the aggressive populations of the root lesion nematode is essential for continuation of carrot production in some locations.

WEEDS

1. ANNUAL GRASSES AND BROADLEAF WEEDS

It is extremely difficult to grow carrots commercially without Lorox and grass herbicides. Cover crops are important to carrot production for erosion control, but must be cleared from the field immediately prior to planting. Cultivation tends to cause root injury, which is especially important in fresh market production.

Preplant herbicides currently registered:

- Glyphosate (Buccaneer, Buccaneer Plus, Cornerstone, Cornerstone Plus, Duplikator 5.5 Plus, Gly-4 Herbicide, Gly Star Original, Glyphos Herbicide, Glyphos X-TRA, Glyphomax, Glyphomax Plus, Glysupreme Plus, Makaze, Mirage, Mirage Plus, Nufarm Credit, Nufarm Credit Extra, Rascal, Rascal Plus, Roundup Original, Roundup Original MAX, Roundup Power MAX, Roundup Ultra Dry, Roundup Ultra MAX, Roundup Ultra MAX II, Roundup Ultra MAX RT, Touchdown,

Touchdown Total, Traxion, Wiseup Plus Glyphosate): Efficacy – excellent. Effective on perennials and good for clearing fields prior to planting. Cannot be used during production or with a wiper (wick) applicator. No residual activity. Classified as a reduced-risk herbicide. Please note this is not a complete list of glyphosate products commercially available.

- Metam potassium (K-Pam HL, Metam KLR54, Sectagon-K-54): Efficacy – good. Kills most annual weeds. Fumigant. Classified as a B2 carcinogen and a carbamate.
- Metam sodium (Vapam HL): Efficacy – unknown. Classified as a B2 carcinogen and a carbamate.

Preemergence herbicides currently registered:

- Trifluralin (Bayonet, Treflan 4L, Treflan HFP, Treflan TR-10, Trifluralin 4EC, Trifluralin 10G, Trifluralin HF, Triflurex HFP): Efficacy – good to fair. An old material, not used much in Michigan; only effective on mineral soils. Effective on grass weeds, weak on some broadleaves and no control of Composites. Applied at low rates, cost effective, and safe on carrots. Must be preplant incorporated. Kills cover crops. Groundwater issues. Classified as a C carcinogen.

Pre- and postemergence herbicides currently registered:

- Linuron (Lorox, Linex): Efficacy – excellent. Without Lorox, Michigan would be currently unable to grow carrots. Effective on organic and mineral soils. No replacement for postemergence application. Effective on broadleaf weeds and safe on carrots. Fast acting. Cost effective, effective at low rates. No residues in the carrot crop. Cover crop grows through it when Lorox is applied preemergence. Development of herbicide resistance in weeds noted. Composites, wild carrot, and nutsedge not controlled. Weed resistance is of concern, especially for marestalk, *Amaranthus* sp. and common purslane. Should not be applied during cloudy weather or when temperature >85°F. Classified as a C carcinogen.

Postemergence herbicides currently registered:

- Clethodim (Arrow 2EC, Clethodim 2E, Intensity Post Emergence Grass Herbicide, Section 2EC, Select 2EC, Select Max, Shadow, Volunteer Herbicide): Efficacy – good. Effective on cover crops and annual grasses. Weak on quackgrass, no broadleaf activity or yellow nutsedge control. At low rates, very cost effective. Minimal crop residues. Acidify water and do not tank mix.
- Fluazifop-P-butyl (Fusilade DX): Efficacy – good. Important grass herbicide, low rates used, cost effective. Very effective on annual grasses and cover crops. Minimal crop residues. Weak on quackgrass, no broadleaf activity or yellow nutsedge control. Risk cup is full (FQPA) and use on carrots may not be continued. Has hard time killing crabgrass once it becomes too large.
- Metribuzin (Dimetric, Metri DF, Metribuzin 75, Metribuzin 75DF, Sencor 4F, Sencor DF, Tricor DF): Efficacy – good. May be substituted for one postemergence Lorox application. Effective on broadleaves; moderate control of composites. Wide weed control spectrum at labeled rates. Active at low rates, cost effective. Injures carrots under some conditions. One application allowed and only at a specific crop size (5-6 leaves). Should not be applied during cloudy weather or when temperature >85°F. One manufacturer has dropped its registration. Classified as a D carcinogen.
- Paraquat dichloride (Gramoxone): Efficacy – good. Apply only before seeding. Classified as a group E chemical.

- Pendimethalin (Prowl H₂O): Efficacy – good. Preemergence. Effective on grass, kills cover crop under some environmental conditions. Safe on carrot. Weak on common lambsquarters, lady’s thumb, composites and mustards. Classified as a C carcinogen.
- Pelargonic acid (Scythe): Efficacy – unknown. Classified as a biopesticide.
- S-metolachlor (Dual Magnum 7.6E): Efficacy – good to fair. Preemergence. Has to be used with Lorox; does not replace it. Yellow nutsedge control and good grass and redroot pigweed control. No effect on cover crops, applied after they are up or killed. Needs water to be activated. Weak on several broadleaves. Short residual. Very active on light soil, potential crop injury on sand. Classified as a reduced-risk herbicide.
- Sethoxydim (Poast 1.5E): Efficacy – good. Important grass herbicide, low rates used, cost effective. Very effective on annual grasses and cover crops. Minimal crop residues. Weak on quackgrass, no broadleaf activity or yellow nutsedge control. Potential resistance.

Other pest management aids:

- Cultivation of cover crops or wind breaks.
- Crop rotation.
- Fall tillage, used in conjunction with herbicide treatments.
- Rotate herbicides to reduce resistance.

Pipeline pest management tools:

- Ethafumesate (Nortron): Efficacy – unknown. Good on some broadleaf weeds.

“To do” list for weeds:

Research needs:

- None identified.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

NUTRIENT MANAGEMENT

Nutrient management is an emerging challenge for growers as processor regulations change. Limiting nitrate loads in soil and crop is of concern. It is also important to be aware of leaching loss.

Pipeline management tools:

- Remote sensing color of crop.

“To do” list for nutrient management:

Research needs:

- Lowering nitrogen levels in roots.
- Compare petiole levels to root levels.
- Determine when to cut off nitrogen to the plants before harvest.
- Slow release fertilizer to avoid nutrient flushes.
- Foliar applications later in season.

- Differences in variety.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

COVER CROPS

Cover crop management impacts soil biology as well as crop characteristics. Cover crops can play a role in disease, insect and weed suppression as well as positively impact soil fertility.

Pipeline management tools:

- Cover crops as rotational crops and biofumigant.

“To do” list for cover crops:

Research needs:

- Suitable crops for carrot production.
- Herbicide carry-over in relation to cover crops.

Regulatory needs:

- None identified.

Educational needs:

- None identified.

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 noncarcinogenicity in humans.
Biopesticide.....	Naturally occurring substances (biochemical), microorganisms (microbial) and pesticidal substances produced by plants containing added genetic material that control pests (EPA).
Reduced-risk	Pesticides which (1) reduce pesticide risks to human health, (2) reduce pesticide risks to nontarget organisms, (3) reduce the potential for contamination of valued, environmental resources, or (4) broaden adoption of integrated pest management or makes it more effective (EPA).

*denotes chemical group is within the larger B2 carcinogen group.

TABLE 2. REGISTERED PESTICIDES FOR CARROTS IN MICHIGAN

Active ingredient	Trade name	Company
FUNGICIDES/BACTERICIDES		
Azoxystrobin	Amistar 80EG Quadris F	Syngenta Crop Protection, Inc. Syngenta Crop Protection, Inc.
Azoxystrobin/chlorothalonil	Quadris Opti 5.5SC	Syngenta Crop Protection, Inc.
<i>Bacillus pumilus</i> QST 2808 strain	Sonata Biofungicide 1.38FL	AgraQuest, Inc.
<i>Bacillus subtilis</i> QST 713 strain	Rhapsody 1.34AS Serenade ASO Serenade MAX 20WP	AgraQuest, Inc. AgraQuest, Inc. AgraQuest, Inc.
Boscalid		BASF Ag Products
Chlorothalonil	Applause 720 Bravo Ultrex 82.5WDG Bravo Weather Stik 6SC Bravo Zn Echo 90DF Echo 75WDG Echo 720 Echo Zn Equus 500 ZN Equus 720 SST Equus DF	Loveland Products, Inc. Syngenta Crop Protection, Inc. Syngenta Crop Protection, Inc. Syngenta Crop Protection, Inc. Sipcam Agro USA, Inc. Sipcam Agro USA, Inc. Sipcam Agro USA, Inc. Sipcam Agro USA, Inc. MANA MANA MANA
Copper hydroxide	Champ DP Dry Prill 57.6DF Champ Formula 2F Champion WP Kocide 101 Kocide 4.5FL Kocide 2000 53.8DF Kocide 3000 Kocide DF Nu-Cop 3L Nu-Cop 50DF Nu-Cop HB	Nufarm Americas, Inc. Nufarm Americas, Inc. Nufarm Americas, Inc. Griffin LLC Griffin LLC Various DuPont Crop Protection Various Albaugh, Inc./Agri Star Albaugh, Inc./Agri Star Albaugh, Inc./Agri Star
Copper, metallic	Copper-Count-N	Mineral Research & Development Corp.
Copper oxide	Nordox 75WG	Monterey Chemical Company
Copper oxychloride	COC DF	Albaugh, Inc./Agri Star
Copper oxychloride sulfate	C-O-C-S WDG	Loveland Products, Inc.
Copper resinate	Tenn-Cop 5E	Griffin LLC
Copper sulfate	Basicop Basic Copper Cuprofix Ultra 40 Disperss	DuPont Crop Protection Albaugh, Inc./Agri Star Cerexagri-Nisso LLC

TABLE 2. REGISTERED PESTICIDES FOR CARROTS IN MICHIGAN

Active ingredient	Trade name	Company
Cyprodinil/fludioxonil	Switch 62.5WG	Syngenta Crop Protection, Inc.
Fludioxonil	Maxim 4FS	Syngenta Crop Protection, Inc.
Iprodione	Iprodione 4L AG Rovral 4F	Various Bayer CropScience
Mefenoxam	Apron XL LS Ridomil Gold EC Ridomil Gold SL Ultra Flourish	Syngenta Crop Protection, Inc. Syngenta Crop Protection, Inc. Syngenta Crop Protection, Inc. Nufarm Americas, Inc.
Mefenoxam/chlorothalonil	Ridomil Gold/Bravo 76.5WP	Syngenta Crop Protection, Inc.
Mefenoxam/copper hydroxide	Ridomil Gold/Copper 65WP	Syngenta Crop Protection, Inc.
Metalaxyl	Allegiance-FL MetaStar 2E AG	Bayer CropScience Arysta LifeScience North America
Mono- and dipotassium salts of phosphorous acid	Fosphite Topaz	J.H. Biotech Winfield Solutions LLC (Agrilience)
Neem oil	Trilogy	Advan, LLC
Pyraclostrobin	Cabrio 20EG	BASF Ag Products
Pyraclostrobin/boscalid	Pristine 38WG	BASF Ag Products
Sulfur	Kumulus DF Microthiol Disperss Micro Sulf Sulfur 6L Sulfur DF Thiolux Jet Yellow Jacket	Micro Flo Company Cerexagri-Nisso LLC Nufarm Americas, Inc. Various Wilbur-Ellis Company Syngenta Crop Protection, Inc. Georgia Gulf Sulfur Corporation
Thiabendazole	Mertect 340-F Dip	Syngenta Crop Protection, Inc.
Thiram	Thiram 42 S Thiram 50WP Dyed	Bayer CropScience Bayer CropScience
Trifloxystrobin	Flint 50WG	Bayer CropScience
INSECTICIDES/NEMATICIDES		
Azadirachtin	Aza-Direct Azatin XL Azatrol EC Ecozin 3%EC Neemix 4.5	Gowan Company OHP, Inc. PBI Gordon Corporation AMVAC Certis USA, L.L.C.
<i>Bacillus thuringiensis</i> subsp. <i>aizawai</i>	XenTari	Valent U.S.A. Corporation

TABLE 2. REGISTERED PESTICIDES FOR CARROTS IN MICHIGAN

Active ingredient	Trade name	Company
<i>Bacillus thuringiensis</i> subsp. <i>kurstaki</i>	Biobit HP	Valent U.S.A. Corporation
	Deliver	Certis USA, L.L.C.
	DiPel DF	Valent U.S.A. Corporation
	DiPel ES	Valent U.S.A. Corporation
	Javelin WG	Advan, LLC
<i>Beauveria bassiana</i> strain GHA	BotaniGard ES	Mycotech
Carbaryl	10% Sevin Granules	Various
	Carbaryl 4L	Various
	Sevin 4F	Bayer CropScience
	Sevin 5 Bait	Wilbur-Ellis Company
	Sevin 80S	Bayer CropScience
	Sevin 80WSP	Bayer CropScience
	Sevin XLR Plus	Bayer CropScience
Cyfluthrin	Baythroid 2	Bayer CropScience
	Baythroid XL	Bayer CropScience
	Renounce 20WP	Bayer CropScience
	Tombstone	Loveland, Inc.
	Tombstone Helios	Loveland, Inc.
Deltamethrin	Battalion 0.2EC	Arysta LifeScience North America
	Delta Gold	Winfield Solutions LLC (Agrilience)
Diazinon	Diazinon 14G	Wilbur-Ellis Company
	Diazinon 5W	Winfield Solutions LLC (Agrilience)
	Diazinon 50W	MANA
	Diazinon AG500	MANA
Endosulfan	Endosulfan 3EC	Various
	Thionex 3EC	MANA
	Thionex 50W	MANA
Esfenvalerate	Adjourn	MANA
	Asana XL	DuPont Agricultural Products
	S-Fenvalo Star	LG Life Sciences
Garlic juice extracts	Allityn	Helena Chemical Company
Harpin protein	N-Hibit	Eden Bioscience Corp.

TABLE 2. REGISTERED PESTICIDES FOR CARROTS IN MICHIGAN

Active ingredient	Trade name	Company
Imidacloprid	Admire 2F	Bayer CropScience
	Admire Pro	Bayer CropScience
	Advise 2FL	Winfield Solutions LLC (Agrilience)
	Alias 2F	MANA
	Couraze 2F	Cheminova, Inc.
	Impulse 1.6FL	Albaugh, Inc./Agri Star
	Macho 2.0FL	Albaugh, Inc./Agri Star
	Montana 2F	Rotam North America, Inc.
	Nuprid 1.6F	Nufarm Americas, Inc.
	Nuprid 2F	Nufarm Americas, Inc.
	Pasada 1.6F	MANA
	Prey 1.6	Loveland Products, Inc.
	Provado 1.6F	Bayer CropScience
	Torrent 2F	Sipcam Agro USA, Inc.
Widow	Loveland Products, Inc.	
Malathion	Malathion 8 Aquamul	Loveland Products, Inc.
	Malathion 57EC	United Agri Products
Methomyl	Lannate LV	DuPont Agricultural Products
	Lannate SP	DuPont Agricultural Products
Oxamyl	Vydate L	DuPont Agricultural Products
Potassium salts of fatty acids	M-Pede	Dow AgroSciences, LLC
Pyrethrin	PyGanic EC 1.4 II	MGK Company
	PyGanic EC 5.0 II	MGK Company
Thiamethoxam	Actara 25WG	Syngenta Crop Protection, Inc.
	Platinum 2SC	Syngenta Crop Protection, Inc.
HERBICIDES		
Clethodim	Arrow 2EC	MANA
	Clethodim 2E	Various
	Intensity	Loveland Products, Inc.
	Section 2EC	Winfield Solutions LLC (Agrilience)
	Select 2EC	Various
	Select Max	Valent U.S.A. Corporation
	Shadow	Arysta LifeScience
	Volunteer Herbicide	TENKOZ, Inc.
Fluazifop-P-butyl	Fusilade DX	Syngenta Crop Protection, Inc.

TABLE 2. REGISTERED PESTICIDES FOR CARROTS IN MICHIGAN

Active ingredient	Trade name	Company
Glyphosate	Buccaneer	TENKOZ, Inc.
	Buccaneer Plus	TENKOZ, Inc.
	Cornerstone	Winfield Solutions LLC (Agriliance)
	Cornerstone Plus	Winfield Solutions LLC (Agriliance)
	Duplikator 5.5 Plus	Drexel Chemical Company
	Gly Star Original	Albaugh, Inc./Agri Star
	Gly-4 Herbicide	Universal Crop Protection Alliance LLC
	Glyfos Herbicide	Cheminova, Inc.
	Glyfos X-TRA	Cheminova, Inc.
	Glyphomax	Dow AgroSciences, LLC
	Glyphomax Plus	Dow AgroSciences, LLC
	Glysupreme Plus	MEY Corporation
	Makaze	Loveland Products, Inc.
	Mirage	Loveland Products, Inc.
	Mirage Plus	Loveland Products, Inc.
	Nufarm Credit	Nufarm Americas, Inc.
	Nufarm Credit Extra	Nufarm Americas, Inc.
	Rascal	Winfield Solutions LLC (Agriliance)
	Rascal Plus	Winfield Solutions LLC (Agriliance)
	Roundup Original	Monsanto Company
	Roundup Original MAX	Monsanto Company
	Roundup Power MAX	Monsanto Company
	Roundup Ultra Dry	Monsanto Company
	Roundup Ultra MAX	Monsanto Company
	Roundup Ultra MAX II	Monsanto Company
	Roundup Ultra MAX RT	Monsanto Company
	Touchdown	Syngenta Crop Protection, Inc.
	Touchdown Total	Syngenta Crop Protection, Inc.
Traxion	Syngenta Crop Protection, Inc.	
Wiseup Plus Glyphosate	MEY Corporation	
Linuron	Linex	Various
	Lorox	Various
Metribuzin	Dimetric	Winfield Solutions LLC (Agriliance)
	Metri DF	Cerexagri-Nisso LLC
	Metribuzin 75	Loveland Products, Inc.
	Metribuzin 75DF	MANA
	Sencor 4F	Bayer CropScience
	Sencor DF	Bayer CropScience
	Tricor DF	Cerexagri-Nisso LLC
Paraquat dichloride	Gramoxone	Syngenta Crop Protection, Inc.
Pendimethalin	Prowl H ₂ O	Dow AgrSciences, LLC
Pelargonic acid	Scythe	Dow AgroSciences, LLC
Sethoxydim	Poast 1.5E	BASF Corporation

TABLE 2. REGISTERED PESTICIDES FOR CARROTS IN MICHIGAN

Active ingredient	Trade name	Company
S-metolachlor	Dual Magnum 7.6E	Syngenta Crop Protection, Inc.
Trifluralin	Bayonet	Helena Chemical Company
	Treflan 4L	Loveland Products, Inc.
	Treflan HFP	Various
	Treflan TR-10	Dow AgroSciences, LLC
	Trifluralin 4EC	Various
	Trifluralin 10G	Loveland Products, Inc.
	Trifluralin HF	Loveland Products, Inc.
	Triflurex HFP	MANA
FUMIGANTS		
1,3-Dichloropropene	Telone II	Dow AgroSciences, LLC
1,3-Dichloropropene/chloropicrin	Pic-Clor 60	Hendrix & Dail, Inc.
	Telone C-17	Dow AgroSciences, LLC
	Telone C-35	Dow AgroSciences, LLC
Chloropicrin	Chloropicrin	Arysta LifeScience North America
	NutraPic Fumigant	Arysta LifeScience North America
Metam potassium	K-Pam HL	Amvac Chemical Corporation
	Metam KLR54	Taminco, Inc.
	Sectagon	Tessengerlo Kerley, Inc. (Nova Source)
Metam sodium	Vapam HL	Amvac Chemical Corporation

TABLE 3. UNREGISTERED FUNGICIDES TESTED ON CARROTS IN MICHIGAN

Active ingredient	Trade name	Company
Cyprodinil	Vanguard	Syngenta Crop Protection, Inc.
Fenbuconazole	Indar	Rohm and Haas Company
Kresoxim-methyl	Sovran	BASF Corporation Ag Products
Mancozeb	Penncozeb 75DF	Cerexagri-Nisso LLC
Tebuconazole	Folicur	Bayer Corporation
Trifloxystrobin/propiconazole	Stratego	Syngenta Crop Protection, Inc.

TABLE 4. DESCRIPTION OF PESTS AND PATHOGENS OF CARROTS IN MICHIGAN

Pest/Pathogen	Symptoms
DISEASE PATHOGENS	
Alternaria leaf spot (<i>Alternaria dauci</i>)	A foliar fungal disease with dark brown/black spots with yellow margins appearing on older leaves and increasing in severity with maturity of the plant. Can result in weak foliage or defoliation, making harvest impossible. Often occurs in association with <i>Cercospora</i> leaf spot.
Aster yellows	A disease caused by a phytoplasma, can cause dwarfing and yellowing of the plant, abnormalities in shape, distortion and fibrousness of roots, and poor flavor resulting in losses in both quality and quantity of yields. It can also predispose plants to other diseases.
Bacterial blight (<i>Xanthomonas campestris</i> pv. <i>carotae</i>)	Yellow-ringed dark blighting on leaves and roots first appear on the lower side of the leaf, then dark streaks may form on the petioles accompanied by a sticky, yellow exudate.
Black root rot..... (<i>Chalara elegans</i>)	A postharvest fungal disease where symptoms develop after washing and packaging carrots. Dark irregular lesions develop on the root surface. Damaged carrots are more likely to become infected.
Black rot	A fungal disease of seedlings resulting in pre- and postemergence damping-off. Older senescing petioles on mature plants are particularly susceptible and provide an avenue for infection of the carrot crown which appears as a black ring of decay where the petioles attach to the root. Symptoms on the carrot, dry, black, sunken lesions, do not appear until after harvest.
Cavity spot..... (<i>Pythium</i> spp.)	A fungal disease that causes elliptical sunken lesions on roots that darken and increase in size with age, which can reduce overall marketable yields.
Cercospora leaf spot (<i>Cercospora carotae</i>)	A foliar fungal disease that starts as small circular brown spots accompanied by yellow/red discoloration on younger leaves. Rapid enlargement can girdle petioles and result in defoliation. Often occurs in association with <i>Alternaria</i> leaf spot.
Crater rot..... (<i>Rhizoctonia carotae</i>)	A fungal disease that infects roots. Symptoms are not evident when harvested, but usually take two to three months to develop in storage. Small craters develop under small white hyphal knots on the root surface and enlarge rapidly to become dry, sunken lesions lined with white cottony mycelium.
Crown rot..... (<i>Rhizoctonia solani</i>)	A fungal disease that infects roots. Horizontal dark brown lesions appear on the root and tops may begin to die in patches. As crop reaches maturity, large deep lesions appear at the top of the carrot.

TABLE 4. DESCRIPTION OF PESTS AND PATHOGENS OF CARROTS IN MICHIGAN

Pest/Pathogen	Symptoms
Damping-off (<i>Pythium</i> spp., <i>Rhizoctonia solani</i>) Root forking, stubbing (<i>Pythium</i> spp., <i>Phytophthora</i> spp.)	Diseases caused by several fungi. Damping-off occurs when infected seedlings wilt, turn brown and die, or develop a water-soaked, discolored stem at the ground level and topple over, resulting in poor stands. Deformation of roots (forking, stubbing) reduces yields.
Fusarium dry rot (<i>Fusarium</i> spp.)	Soilborne fungi that cause brown, leathery lesions and side cankers and decay of crowns. Warm temperatures and wounding of carrot roots facilitates the growth and spread of this disease. Rapid growth of the fungi can occur in storage if given free moisture and favorable temperatures.
Gray mold (<i>Botrytis</i> spp.)	Primarily a storage problem; not considered a typical problem in the field.
Phytophthora root rot or rubbery brown rot (<i>Phytophthora cactorum</i>)	A fungal-like pathogen that causes dark brown to black, water-soaked lesions and a rubbery consistency of the root. Lesions occur in one or more bands anywhere on the carrot root. White mycelia may be present on lesions, which facilitates the spread of the pathogen.
Powdery mildew (<i>Erysiphe polygoni</i>)	A fungal disease that first appears on the lower leaves, with mycelium and powdery spores covering the surface of the leaves and interfering with photosynthesis. Weakening of foliage causes harvesting problems, and the disease can significantly reduce yields.
Root dieback (<i>Pythium</i> spp.)	This fungal-like pathogen kills young tap roots after seed germination, reducing root length and/or stimulating forking. Infected roots may become excessively branched or stubbed.
Sour rot (<i>Geotrichum candidum</i>)	A fungal disease that infects carrots through wounds. A soft, watery, colorless decay develops on roots. Infection first occurs in the field and can continue during storage.
White mold (<i>Sclerotinia sclerotiorum</i>)	A fungal disease evidenced by white, cottony growth on carrot surfaces in the ground and in storage. Infected tissues become dark, soft and watery.
INSECTS	
Aster leafhopper (<i>Macrostelus quadrilineatus</i>)	Adults and nymphs pierce the vascular tissues of the plant to extract sap. They vector aster yellows disease.
Carrot weevil (<i>Listronotus oregonensis</i>)	Adults lay eggs in leaf petioles and leave small circular feeding holes on the underside of leaf petioles. Larvae tunnel in the outer surface of the roots which reduces quality, and can kill or damage the plant.
Cutworm (Noctuidae)	Larvae can cause severe petiole damage and defoliation.

TABLE 4. DESCRIPTION OF PESTS AND PATHOGENS OF CARROTS IN MICHIGAN

Pest/Pathogen	Symptoms
Green peach aphid (<i>Myzus persicae</i>)	Aphids can cause twisting and distortion of new growth by sucking plant sap, and can be a contaminant at harvest. They can also transmit viruses.
NEMATODES	
Carrot cyst nematode (<i>Heterodera carotae</i>)	Roots become shallow and disfigured, and foliage becomes stunted, chlorotic and wilted. Nematodes live in roots and inject toxins while feeding, severely reducing yield.
Northern root knot nematode..... (<i>Meloidogyne hapla</i>)	Root knot nematodes can severely reduce carrot quality and yields by causing galls, forking and bunching of roots by feeding on and living in roots.
Pin nematode (<i>Paratylenchus</i> sp.)	Pin nematodes can retard root growth and affect the development of orange pigment.
Root lesion nematode (<i>Pratylenchus penetrans</i>)	Root lesion nematodes cause necrosis, discoloration, stunting and disfiguration by burrowing into the carrot root to feed.
WEEDS	
Barley (<i>Hordeum vulgare</i>)	Commonly used as a cover crop. Can become a problem if not killed at the proper time.
Large crabgrass..... (<i>Digitaria sanguinalis</i>)	A summer annual that can grow prostrate and spreading or ascending to 3 feet in height.
Barnyard grass (<i>Echinochloa crus-galli</i>)	A summer annual with erect, thick clump-forming stems (5 feet tall). No ligules.
Field sandbur (<i>Cenchrus incertus</i>)	An annual grass that produces numerous green- to straw-colored spiny burs at maturity.
Fall panicum (<i>Panicum dichotomiflorum</i>)	A summer annual with an erect to sprawling or kneeling habit.
Common lambsquarters..... (<i>Chenopodium album</i>)	An erect summer annual with a gray-mealy coating, particularly on the surfaces of younger leaves.
Common purslane..... (<i>Portulaca oleracea</i>)	A summer annual with a prostrate mat-forming habit and thick, succulent stems and leaves.
Lady's thumb..... (<i>Persicaria vulgaris</i>)	An erect or ascending much-branched summer annual.
Redroot pigweed..... (<i>Amaranthus palmeri</i>)	An erect freely branching summer annual. The small flowers are enclosed by spiny bracts that give the terminal and axillary spikes a bristly appearance. They have a shallow taproot, often pinkish or reddish.
Common ragweed..... (<i>Ambrosia artemisiifolia</i>)	An erect, branching, summer annual.

TABLE 4. DESCRIPTION OF PESTS AND PATHOGENS OF CARROTS IN MICHIGAN

Pest/Pathogen	Symptoms
Swamp dodder (<i>Cuscuta gronovii</i>)	A parasitic annual vine lacking chlorophyll and distinct leaves. Thread-like stems twine on other plants and are yellow, orange, or red.
Marestail (<i>Conyza canadensis</i>)	A winter or summer annual. Seedlings develop into a basal rosette. Mature plants produce an erect central stem with a terminal panicle of inconspicuous flowers.
Wild carrot..... (<i>Daucus carota</i>)	A biennial forming a basal rosette of leaves for the first year and an erect flowering stalk the following year. The foliage is fern-like with a carrot-like odor.
Yellow nutsedge (<i>Cyperus esculentus</i>)	A perennial with triangular stems, long grass-like leaves, yellowish green foliage, and ½-1 inch long tubers at the ends of rhizomes. Flowers are spikelets at the ends of the stems.
Pineapple weed..... (<i>Chamomilla suaveolens</i>)	A low-growing, bushy, branching summer or winter annual, reaching 2-16 inches in height with finely divided pinnately compound leaves. Crushed leaves have a sweet odor similar to pineapple.
Common groundsel..... (<i>Senecio vulgaris</i>)	A branched, erect, winter or summer annual. Leaves are deeply lobed to dissected, irregularly toothed, and somewhat fleshy.

TABLE 5. ADVANTAGES AND DISADVANTAGES OF PESTICIDES FOR CARROTS

Active	Pest	Advantages/Disadvantages
FUNGICIDES		
azoxystrobin	Alternaria leaf blight Cercospora leaf spot	<ul style="list-style-type: none"> • Broad control spectrum. • Low application rates and intervals comparable to or longer than most alternatives. • Practically nontoxic to birds, mammals, honeybees. • Highly toxic to freshwater fish and invertebrates. • Risk of fungicide resistance. • Reduced-risk fungicide.
azoxystrobin/ chlorothalonil	Alternaria leaf blight Cercospora leaf spot	<ul style="list-style-type: none"> • Azoxystrobin: Reduced-risk fungicide. • Chlorothalonil: B2 carcinogen.
<i>Bacillus pumilus</i> QST 2808 strain	Powdery mildew White mold	<ul style="list-style-type: none"> • Biopesticide.
<i>Bacillus subtilis</i> QST 713 strain	Bacterial leaf blight Black rot Gray mold rot Powdery mildew White mold	<ul style="list-style-type: none"> • Biopesticide.
boscalid	Alternaria leaf blight	<ul style="list-style-type: none"> • Reduced-risk fungicide.
chlorothalonil	Alternaria leaf blight Cercospora leaf spot	<ul style="list-style-type: none"> • Broad spectrum foliar protectant fungicide. • .B2 carcinogen. • Cost effective.
copper compounds	Alternaria leaf blight Cercospora leaf spot Bacterial blight	<ul style="list-style-type: none"> • Toxic to fish. • Limited efficacy under severe disease pressure. • Broad spectrum protectant fungicide and bactericide.
cyprodinil/ fludioxonil	Alternaria leaf blight	<ul style="list-style-type: none"> • Reduced-risk fungicide.
fludioxonil	Damping-off	<ul style="list-style-type: none"> • Seed treatment. • Toxic to fish and aquatic invertebrates. • Reduced-risk fungicide.
iprodione	Alternaria leaf blight	<ul style="list-style-type: none"> • B2 carcinogen. • Some systemic activity. • Expensive. • Important as a seed treatment.
mefenoxam	Damping off Root forking/stubbing	<ul style="list-style-type: none"> • Resistance is a concern. • Corrosive. • Long lasting activity. • Reduced-risk fungicide.

TABLE 5. ADVANTAGES AND DISADVANTAGES OF PESTICIDES FOR CARROTS

Active	Pest	Advantages/Disadvantages
mefenoxam/ chlorothalonil	Cavity spot	<ul style="list-style-type: none"> • Mefenoxam: Resistance concerns, corrosive, reduced-risk fungicide. • Long lasting activity. • Chlorothalonil: Broad spectrum foliage protectant fungicide, B2 carcinogen.
mefenoxam/ copper hydroxide	Cavity spot	<ul style="list-style-type: none"> • Mefenoxam: Resistance concerns, corrosive, reduced-risk fungicide. • Long lasting activity. • Copper hydroxide: Toxic to fish.
metalaxyl	Cavity spot Damping off	<ul style="list-style-type: none"> • Reduced-risk fungicide. • Resistance concerns.
mono- and dipotassium salts of phosphorous acid	Damping off	<ul style="list-style-type: none"> • Biopesticide.
neem oil	Cercospora leaf spot Powdery mildew White mold	<ul style="list-style-type: none"> • Biopesticide.
pyraclostrobin	Alternaria leaf blight Cercospora leaf spot	<ul style="list-style-type: none"> • Resistance concerns.
pyraclostrobin/ boscalid	Alternaria leaf blight Cercospora leaf spot Powdery mildew	<ul style="list-style-type: none"> • Reduced-risk fungicide. • Resistance concerns.
sulfur	Powdery mildew	<ul style="list-style-type: none"> • Very safe chemical. • Effectiveness is related to the fineness of the particles.
thiabendazole	Gray mold Sclerotinia rot	<ul style="list-style-type: none"> • None identified.
thiram	Damping-off	<ul style="list-style-type: none"> • Seed treatment. • Broad-spectrum, less expensive than alternatives.
trifloxystrobin	Alternaria leaf blight	<ul style="list-style-type: none"> • Reduced-risk fungicide. • Will likely be expensive. • Not considered a risk to birds, mammals and honeybees because of low toxicity. • Highly toxic to fish and aquatic invertebrates but not expected to occur in concentrations high enough to be risky. • Risk of fungicide resistance.

TABLE 5. ADVANTAGES AND DISADVANTAGES OF PESTICIDES FOR CARROTS

Active	Pest	Advantages/Disadvantages
UNREGISTERED FUNGICIDES		
cyprodinil	Alternaria leaf blight Cercospora leaf spot	<ul style="list-style-type: none"> • Will likely be expensive. • Practically nontoxic to birds, small mammals, bees, earthworms. • Moderately toxic to fish. • Very highly toxic to freshwater/marine invertebrates. • Risk of fungicide resistance. • Reduced-risk fungicide.
fenbuconazole	Alternaria leaf blight	<ul style="list-style-type: none"> • Risk of fungicide resistance.
kresoxim-methyl	Alternaria leaf blight	<ul style="list-style-type: none"> • Will likely be expensive. • Data suggests it will have a tendency to accumulate in fish. • Risk of fungicide resistance.
mancozeb	Alternaria leaf blight Cercospora leaf spot	<ul style="list-style-type: none"> • B2 carcinogen.
tebuconazole	Alternaria leaf spot	<ul style="list-style-type: none"> • Risk of fungicide resistance.
trifloxystrobin/ propiconazole	Alternaria leaf spot	<ul style="list-style-type: none"> • Trifloxystrobin: Reduced-risk fungicide. Not considered a risk to birds, mammals and honeybees because of low toxicity. • Will likely be expensive. • Highly toxic to fish and aquatic invertebrates but not expected to occur in concentrations high enough to be risky. • Risk of fungicide resistance.
INSECTICIDES/NEMATICIDES		
1,3-Dichloropropene	Nematodes	<ul style="list-style-type: none"> • Cannot use on heavy soil. • Particularly effective against cyst-forming and meadow nematodes, also helps control weeds and diseases. • B2 carcinogen.
azadirachtin	Aphids Aster leafhoppers Carrot weevil Cutworms Nematodes	<ul style="list-style-type: none"> • Biopesticide.
<i>Bacillus thuringensis</i> subsp. <i>aizawai</i>	Cutworms	<ul style="list-style-type: none"> • Biopesticide.

TABLE 5. ADVANTAGES AND DISADVANTAGES OF PESTICIDES FOR CARROTS

Active	Pest	Advantages/Disadvantages
<i>Bacillus thuringiensis</i> subsp. <i>kurstaki</i>	Cutworms	<ul style="list-style-type: none"> • Biopesticide.
<i>Beauveria bassiana</i> strain GHA	Aphids	<ul style="list-style-type: none"> • Biopesticide.
carbaryl	Aster leafhoppers	<ul style="list-style-type: none"> • Toxic to beneficial insects. • Excessive use leads to aphid outbreak. • Very effective against chewing insects, fast acting. • Carbamate insecticide.
cyfluthrin	Aster leafhoppers Carrot weevils Cutworms	<ul style="list-style-type: none"> • Toxic to fish, not effective against sub-surface soil insects. • Very effective against chewing insects, fast acting. • Not as effective at high temperatures, can result in buildup of aphid populations.
deltamethrin	Aphids Cutworms	<ul style="list-style-type: none"> • None identified.
diazinon	Aphids	<ul style="list-style-type: none"> • Toxic to bees and birds. • Long residual time, good efficacy. • Organophosphate pesticide.
endosulfan	Aphids Aster leafhoppers	<ul style="list-style-type: none"> • Relatively nontoxic to bees, highly toxic to fish, corrosive to iron. • Moderate efficacy.
esfenvalerate	Aster leafhoppers Carrot weevils Cutworms	<ul style="list-style-type: none"> • Toxic to mite and aphid predators. • High efficacy rate for control of leafhoppers. • Not as effective at high temperatures.
garlic juice extracts	Aster leafhoppers Carrot weevil	<ul style="list-style-type: none"> • Biopesticide.
harpin protein	Nematodes	<ul style="list-style-type: none"> • Biopesticide.
imidacloprid	Aphids Aster leafhoppers	<ul style="list-style-type: none"> • None identified.
malathion	Aphids Aster leafhoppers	<ul style="list-style-type: none"> • Broad spectrum insecticide that is toxic to beneficial insects. • Expensive. • Low mammalian toxicity. • Organophosphate pesticide.
metam sodium	Nematodes	<ul style="list-style-type: none"> • Very expensive. • Highly efficient. • Controls bacteria, fungi, weeds and soil insects. • Carbamate, B2 carcinogen.

TABLE 5. ADVANTAGES AND DISADVANTAGES OF PESTICIDES FOR CARROTS

Active	Pest	Advantages/Disadvantages
methomyl	Aster leafhoppers Cutworms	<ul style="list-style-type: none"> • Toxic to bees, birds and fish. • Moderate efficacy, fast acting. • Carbamate insecticide.
oxamyl	Carrot weevils Nematodes	<ul style="list-style-type: none"> • Systemic insecticide that is translocated downward. • Moderate efficacy. • Carbamate pesticide.
potassium salts of fatty acids	Aphids Aster leafhoppers	<ul style="list-style-type: none"> • Biopesticide.
thiamethoxam	Aphids Aster leafhoppers	<ul style="list-style-type: none"> • None identified.
HERBICIDES		
clethodim	Grasses	<ul style="list-style-type: none"> •
fluazifop-P-butyl	Grasses	<ul style="list-style-type: none"> • Broadleaf crops are tolerant, higher rate needed on quackgrass. • Limit 6 pints per acre per year.
glyphosate	Annual grasses Broadleaf weeds	<ul style="list-style-type: none"> • Excellent efficacy, nonresidual. • Can control dense stands of perennials other herbicides cannot. • Slightly toxic to birds, practically nontoxic to fish, aquatics, honeybees. • Reduced-risk herbicide.
linuron	Annual grasses Broadleaf weeds	<ul style="list-style-type: none"> • Not effective on perennial weeds. • Can harm young seedlings. • Cannot apply at temperatures $\geq 85^{\circ}\text{F}$ and pressures ≥ 40 psi. • Weeds of Compositae family beginning to show resistance. • Very effective on muck soils. • Minimal risk to honeybees. • Chronic risk to birds. • Chronic effects in wild mammals likely. • Group C carcinogen.
metribuzin	Broadleaf weeds	<ul style="list-style-type: none"> • Good efficacy, control lasts 3-4 months. • Higher rates needed on soils with high organic matter. • Do not apply during cloudy weather or when temperature $> 85^{\circ}\text{F}$. • Relative inexpensive. • Can cause phytotoxicity. • Group D carcinogen.

TABLE 5. ADVANTAGES AND DISADVANTAGES OF PESTICIDES FOR CARROTS

Active	Pest	Advantages/Disadvantages
paraquat dichloride	Annual grasses Broadleaf weeds Perennial weeds	<ul style="list-style-type: none">• None identified.
pelargonic acid	Annual grasses Broadleaf weeds Perennial weeds	<ul style="list-style-type: none">• Biopesticide.
sethoxydim	Grasses	<ul style="list-style-type: none">• Selective for emerged grasses.• Not effective at temperatures <60°F.• Established grasses may need two applications.
S-metolachor	Annual grasses	<ul style="list-style-type: none">• Must be used with Lorox.• Short residual.
trifluralin	Annual grasses Broadleaf weeds	<ul style="list-style-type: none">• Good grass control.• Kills weed seeds as they germinate.• Rainfall not required.• Must incorporate into soil within 24 hours for best effectiveness.• Not very effective on muck soils.• Group C carcinogen.

TABLE 6. EFFICACY OF PEST MANAGEMENT TOOLS FOR CONTROL OF DISEASES OF CARROT

Management tool	Diseases of carrots ¹															
	ALS	AY	BB	BR	BRR	CS	CLS	CR	CRR	DO/RFS	FDR	GM	PM	PRR/RBR	SR	WM
B2 CARCINOGENIC FUNGICIDES REGISTERED IN MI																
1,3-dichloropropene (Telone II) (fumigant)	-	-	-	-	-	G	-	G	G	G	G	-	-	G	-	G
1,3-dichloropropene/ chloropicrin (Telone C-17,C-35, Pic-Clor 60) (fumigant)	-	-	-	-	-	G	-	G	G	G	G	-	-	G	-	G
azoxystrobin/chlorothalonil (Quadris Opti)	E	-	-	-	-	-	E	-	-	-	-	-	-	-	-	-
chlorothalonil (Bravo)	G-E	-	-	-	-	-	G-E	-	-	-	-	-	-	-	-	-
iprodione (Rovral)	G-E	-	-	G	-	-	G-E	-	-	-	-	-	-	-	-	-
mefenoxam/chlorothalonil (Ridomil Gold)	-	-	-	-	-	G	-	-	-	-	-	-	-	-	-	-
metam potassium (K-Pam, Sectagon) (fumigant)	-	-	-	-	-	G	-	?	-	-	-	-	-	-	-	-
metam sodium (Vapam) (fumigant)	-	-	-	-	-	G	-	?	-	G	G	-	-	-	-	?
OTHER FUNGICIDES REGISTERED IN MI																
azoxystrobin (Quadris)	G-E	-	-	-	-	-	G-E	-	-	-	-	-	-	-	-	-
<i>Bacillus pumilis</i> (Sonata Biofungicide)	-	-	P	-	-	-	-	-	-	-	-	-	P	-	-	P
<i>Bacillus subtilis</i> (Rhapsody, Serenade)	-	-	-	P	-	-	-	-	-	-	-	P	P	-	-	P
boscalid (Endura)	G-E	-	-	-	-	-	G-E	-	-	-	-	-	-	-	-	-

TABLE 6. EFFICACY OF PEST MANAGEMENT TOOLS FOR CONTROL OF DISEASES OF CARROT

Management tool	Diseases of carrots ¹															
	ALS	AY	BB	BR	BRR	CS	CLS	CR	CRR	DO/RFS	FDR	GM	PM	PRR/RBR	SR	WM
chloropicrin (Chloropicrin, NutraPic) (fumigant)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
copper hydroxide (Champ, Kocide, Nu-Cop)	F-P	-	P-F	-	-	-	F-P	-	-	-	-	-	-	-	-	-
copper, metallic (Copper-Count-N)	P	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-
copper oxide (Nordox 75WG)	F-P	-	-	-	-	-	F-P	-	-	-	-	-	-	-	-	-
copper oxychloride (COC DF)	F-P	-	-	-	-	-	F-P	-	-	-	-	-	-	-	-	-
copper oxychloride sulfate (C-O-C-S WDG)	F-P	-	-	-	-	-	F-P	-	-	-	-	-	-	-	-	-
copper resinate (Tenn-Cop 5E)	P	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-
copper sulfate (Basicop, Cuprofix)	P	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-
cyprodinil/fludioxonil (Switch 62.5WG)	G	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-
fludioxonil (Maxim 4FS)	-	-	-	-	-	-	-	-	-	F	-	-	-	-	-	-
mefenoxam (Apron XL LS, Ridomil Gold)	-	-	-	-	-	F-G	-	-	-	F	-	-	-	-	-	-
mefenoxam/copper hydroxide (Ridomil Gold/Copper)	-	-	-	-	-	F	-	-	-	-	-	-	-	-	-	-
metalaxyl (Allegiance-FL, MetaStar 2E AG)	-	-	-	-	-	G	-	-	-	F-G	-	-	-	-	-	-

TABLE 6. EFFICACY OF PEST MANAGEMENT TOOLS FOR CONTROL OF DISEASES OF CARROT

Management tool	Diseases of carrots ¹															
	ALS	AY	BB	BR	BRR	CS	CLS	CR	CRR	DO/RFS	FDR	GM	PM	PRR/RBR	SR	WM
mono- and dipotassium salts of phosphorous acid (Fosphite, Topaz)	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-	-
neem oil (Trilogy)	P	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-
pyraclostrobin (Cabrio EG)	E	-	-	-	-	-	E	-	-	-	-	-	G	-	-	-
pyraclostrobin/boscalid (Pristine)	E	-	-	-	-	-	E	-	-	-	-	-	E	-	-	-
sulfur (Kumulus, Microthiol Special, Thiolux)	-	-	-	-	-	-	-	-	-	-	-	-	F	-	-	-
thiabendazole (Mertect 340-F Dip)	-	-	-	-	-	-	-	-	-	-	-	F	-	-	-	-
thiram (Thiram)	-	-	-	-	-	-	-	-	-	F	-	-	-	-	-	-
trifloxystrobin (Flint)	E	-	-	-	-	-	E	-	-	-	-	-	G	-	-	F
PIPELINE PEST MANAGEMENT TOOLS																
<i>Ampelomyces quisqualis</i> (AQ10® Biofungicide)	ND	-	ND	-	-	ND	ND	ND	-	ND	-	-	ND	-	-	ND
cyprodinil (Vanguard)	G-E	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-
fenbuconazole (Indar)	E	-	-	-	-	-	P-F	-	-	-	-	-	-	-	-	-
kresoxim-methyl (Sovran)	E	-	-	-	-	-	E	-	-	-	-	-	-	-	-	-
mancozeb (Penncozeb)	G	-	-	-	-	-	G	-	-	-	-	-	-	-	-	-
tebuconazole (Folicur)	P-F	-	-	-	-	-	P-F	-	-	-	-	-	-	-	-	-
trifloxystrobin/propiconazole (Stratego)	E	-	-	-	-	-	G	-	-	-	-	-	-	-	-	-

TABLE 6. EFFICACY OF PEST MANAGEMENT TOOLS FOR CONTROL OF DISEASES OF CARROT

Management tool	Diseases of carrots ¹															
	ALS	AY	BB	BR	BRR	CS	CLS	CR	CRR	DO/RFS	FDR	GM	PM	PRR/RBR	SR	WM
OTHER PEST MANAGEMENT AIDS																
Crop rotation	P-F	P	P			P-F	P-F	P-F		P-F			P			P-F
Disease-free seed	F	-	F	-	-	-	F	-	-	-	-	-	-	-	-	-
Early planting	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND
Plant at correct soil temp	-	-	-	-	-	-	-	-	-	F	-	-	-	-	-	-
Postharvest tilling	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Regulate soil moisture, leaf wetness	ND	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Remove infected plants	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF
Tolerant/resistant varieties	P-G	P-G	ND	-	-	ND	P-G	ND	-	ND	-	-	ND	-	-	ND
Weed control	P	P	P	-	-	P	P	P	-	P	-	-	P	-	-	P
<i>Xanthomonas</i> -indexed seed	-	-	NF	-	-	-	-	-	-	-	-	-	-	-	-	-

¹Disease abbreviations: ALS = Alternaria leaf spot, AY = aster yellows, BB = bacterial blight, BR = black rot, BRR = black root rot, CS = cavity spot, CLS = Cercospora leaf spot, CR = crater rot, CRR = crown rot, DO/RFS = damping off/root forking and stubbing, FDR = Fusarium dry rot, GM = gray mold, PM = powdery mildew, PRR/RBR = Phytophthora root rot/rubbery brown rot, SR = sour rot, WM = white mold.

²Efficacy rating symbols: E = excellent (90-100% control), G = good (80-90% control), F = fair (70-80% control), P = poor (<70% control), ? = no data but suspected of being efficacious, - = not applicable, not used and/or not suspected of being efficacious, ND = no data, NF = not feasible, NR = registered for use, but not recommended.

TABLE 7. EFFICACY OF PEST MANAGEMENT TOOLS FOR CONTROL OF INSECTS AND NEMATODES OF CARROT

Management tool	Insects ¹				Nematodes ¹			
	CW	C	GPA	LH	CCN	NRKN	PN	RLN
CARBAMATES REGISTERED IN MI								
carbaryl (Sevin)	- ²	-	-	E	-	-	-	-
oxamyl (Vydate)	G	-	-	-	P-E	P-E	-	P-E
ORGANOPHOSPHATES REGISTERED IN MI								
diazinon (Diazinon)	-	-	G	-	-	-	-	-
malathion (Malathion)	-	-	G	G	-	-	-	-
OTHER B2 CARCINOGEN INSECTICIDES AND NEMATICIDES REGISTERED IN MI								
1,3-dichloropropene (Telone)	-	-	-	-	G-E	G-E	-	G-E
metam sodium (Vapam)	-	-	-	-	G-E	E	-	E
OTHER INSECTICIDES AND NEMATICIDES REGISTERED IN MI								
azadirachtin (Neemix)	-	?	-	?	-	-	-	-
<i>Bacillus thuringiensis</i> subsp. <i>aizawai</i> (XenTari)	-	-	-	-	-	-	-	-
<i>Bacillus thuringiensis</i> subsp. <i>kurstaki</i> (Biobit, Dipel,	-	-	-	-	-	-	-	-
<i>Beauveria bassiana</i> strain GHA (BotaniGard ES)	-	-	-	-	-	-	-	-
cyfluthrin (Baythroid)	E	E	-	E	-	-	-	-
deltamethrin (Battalion, Delta Gold)	-	-	-	-	-	-	-	-
endosulfan (Phaser, Thiodan)	-	-	G	-	-	-	-	-
esfenvalerate (Asana)	E	E	-	E	-	-	-	-
garlic juice extracts (Allityn)	-	-	-	-	-	-	-	-
harpin protein (N-Hibit)	-	-	-	-	-	-	-	-
imidacloprid (Provado)	-	-	-	F-G ?	-	-	-	-
methomyl (Lannate)	-	G	-	E	-	-	-	-

TABLE 7. EFFICACY OF PEST MANAGEMENT TOOLS FOR CONTROL OF INSECTS AND NEMATODES OF CARROT

Management tool	Insects ¹				Nematodes ¹			
	CW	C	GPA	LH	CCN	NRKN	PN	RLN
oxamyl (Vydate)	–	–	–	–	–	–	–	–
potassium salts of fatty acids (M-Pede)	–	–	–	–	–	–	–	–
pyrethrin (PyGanic)	–	–	–	–	–	–	–	–
thiomethoxam (Actara, Platinum)	–	–	–	–	–	–	–	–
PIPELINE PEST MANAGEMENT TOOLS								
methoxyfenozide (Intrepid or Runner)	ND	G?	ND	?	ND	ND	ND	ND
OTHER PEST MANAGEMENT AIDS								
Cover crops (oilseed radish, marigold)	–	–	–	–	?	?	?	?
Crop rotation	G	?	–	P	F-G	G-E	?	NF
Early planting	–	–	–	NF	–	–	–	–
Field selection	?	E	?	?	?	?	?	?
Natural enemies (biocontrols)	–	?	–	–	?	?	–	?
Removal of infected plants	NF	NF	NF	NF	NF	NF	NF	NF
Sanitation	–	–	–	–	?*	?*	?*	?*
Trap crops	ND	ND	ND	?	–	–	–	–
Varietal selection	ND	ND	ND	?	ND	ND	ND	ND
Weed control	?	?	?	?	–	–	–	–

¹Pest abbreviations: CW = carrot weevil, CCN = carrot cyst nematode, C = cutworm, GPA = green peach aphid, LH = Leafhopper, NRKN = northern root knot nematode, PN = pin nematode, RLN = root lesion nematode.

²Efficacy rating symbols: E = excellent (90-100% control), G = good (80-90% control), F = fair (70-80% control), P = poor (<70% control), ? = no data but suspected of being efficacious, – = not applicable, not used and/or not suspected of being efficacious, ND = no data, NF = not feasible, NR = registered for use, but not recommended.

*May prevent spread of nematodes to fields not already infested with nematodes.

TABLE 8. EFFICACY OF PEST MANAGEMENT TOOLS FOR CONTROL OF WEEDS OF CARROT

Management tool	Weeds of carrots ¹															
	BA	LC	BG	FS	FP	CL	CP	LT	RP	CR	SD	MT	WC	YN	PW	CG
REGISTERED HERBICIDES																
clethodim (Select)	E	E	E	E	G	P	P	P	P	P	P	P	P	P	P	P
fluazifop-p-butyl (Fusilade)	E ²	G*	E	E	G	P	P	P	P	P	P	P	P	P	P	P
glyphosate (Roundup)	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
linuron (Linex, Lorox)	–	F	G	F	F	E	G*	G	F-G	F	P	F	P	P	F	P
metribuzin (Sencor)	–	F	G	F-P	F	E	G	G	F-G	F-G	–	F	P	P	F	F
paraquat dichloride (Gramoxone)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
pelargonic acid (Scythe)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
pendimethalin (Prowl)	–	G	E	G	F	G	F	F	F	F	F	F	P	P	F	F
s-metolachlor (Dual Magnum)	–	G	G	F	P	F	F	F	G	F	P	P	P	G	F	F
sethoxydim (Poast)	E	G*	E	E	G	P	P	P	P	P	P	P	P	P	P	P
trifluralin (Treflan, Trilin)	–	G	G	F	G	G	G	F	G	P	P	P	P	P	P	P
PIPELINE PEST MANAGEMENT TOOLS																
flumioxazin (Valor)	–	G	G	F	F	G	G	G	G	G	P	G	P	P	F	F
OTHER PEST MANAGEMENT AIDS																
Cultivation	–	G	G	G	G	G	G	G	G	G	P	G	G	P	G	G
Mulching/composting	–	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Rotation	–	G	G	G	G	P	G	G	P	G	G	P	G	P	P	P

¹Weed abbreviations key: BA = barley, LC = large crabgrass, BG = barnyardgrass, FS = field sandbur, FP = fall panicum, CL = common lambsquarters, CP = common purslane, LT = lady's thumb, RP = redroot pigweed, CR = common ragweed, SD = swamp dodder, MT = maretail, WC = wild carrot, YN = yellow nutsedge, PW = pineapple weed, CG = common groundsel.

²Efficacy rating symbols: E = excellent (90-100% control), G = good (80-90% control), F = fair (70-80% control), P = poor (<70% control), ? = no data but suspected of being efficacious, – = not applicable, not used and/or not suspected of being efficacious, NR = registered for use, but not recommended

*Some resistance has been seen.

TABLE 9. GENERAL TIMELINE FOR CROP STAGES, WORKER ACTIVITIES AND KEY PESTS ON CARROTS

Crop stages	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Planting	■	■							
Cotyledon		■	■						
First true leaf		■	■						
Closed canopy				■	■	■	■	■	
Harvest					■	■	■	■	
Worker Activities	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Planting	■	■							
Scouting			■	■	■				
Disease control			■	■	■	■			
Insect control			■	■	■	■			
Weed control		■	■						
Cultivation-mechanical	■	■	■						
Hand weeding				■	■				
Fertilization			■	■	■				
Irrigation (variable)	■	■	■	■	■				
Harvest						■	■	■	
Diseases	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alternaria leaf spot				■	■	■			
Aster yellows				■	■	■			
Bacterial blight				■	■	■			
Black root rot									
Black rot									
Cavity spot					■	■			
Cercospora leaf spot			■	■	■	■			
Crater rot					■	■	■		
Crown rot									
Damping off/root forking, stubbing		■	■						
Fusarium dry rot									■

Diseases continued	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Phytophthora root rot/rubbery brown rot									
Powdery mildew									
Root dieback									
Sour rot									
White mold									
Insect pests	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Carrot weevil									
Cutworms									
Green peach aphids									
Leafhoppers									
Nematode pests	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Carrot cyst nematode									
Northern root knot nematode									
Pin nematode									
Root lesion nematode									