PEST MANAGEMENT IN THE FUTURE

A Strategic Plan for the Michigan Carrot Industry

Workshop Summary
March 1-2, 2000
Michigan State University
East Lansing, Michigan

TABLE OF CONTENTS

WORKSHOP PARTICIPANTS

John Bakker	Crop Consultant, Westcentral Michigan Crop Management Association
Tom Benner	Pesticide & Plant Pest Mgt. Div., Michigan Department of Agriculture
George Bird	Department of Entomology, Michigan State University
Beth Bishop	Department of Entomology, Michigan State University
Bob Boehm	Michigan Farm Bureau
Gary Brandt	Grower; Carrot Commission
Jim Breinling	Michigan State University Extension
Wilfred Burr	USDA, Office of Pest Management Policy
Tom Bury	Grower; Carrot Commission
Todd DeKryger	Gerber Products Corp.; Michigan IPM Alliance
Charles Edson	Center for Integrated Plant Systems, Michigan State University
Bob Eppelheimer	Michigan Potato and Carrot Commission
Chris Falak	Gerber Products Corp.; The Michigan Vegetable Council, Inc.
Craig Harris	Department of Sociology, Michigan State University
Mary Hausbeck	Department of Botany and Plant Pathology, Michigan State University
Nick Hether	Gerber Products Corp.
David Iott	Grower
Lynnae Jess	Pesticide Impact Assessment Program, Michigan State University
Margaret Jones	Environmental Protection Agency
Kent Karnemaat	Grower; The Michigan Vegetable Council, Inc.
Ken Oomen	Grower; Carrot Commission
Tom Oomen	Grower
Walter Pett	Department of Entomology, Michigan State University
Robin Rosenbaum	Pesticide & Plant Pest Mgt. Div., Michigan Department of Agriculture
Chris Vandervoort	Center for Integrated Plant Systems, Michigan State University
Glen Vogel	Grower
Todd Young	Grower; Carrot Commission Chairperson
Bernard Zandstra	Department of Horticulture, Michigan State University

ABOUT THE WORKSHOP

A group of growers, processors and technical experts met in East Lansing, Michigan for one and a half days to determine and summarize 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. The participants were divided into three representative groups to discuss a specific range of pests in order to report back to the entire group. The first group covered insects and nematode pests; the second group covered fungal, bacterial and mycoplasma-like organisms (MLO); and the third group covered weed management. The top critical research, regulatory and education needs were determined after the three groups were brought back together.

TOP PRIORITIES OF MICHIGAN CARROT PRODUCTION

Research:*

1. Identify effective reduced-risk fungicides and/or biocontrol agents and develop disease predictors to manage foliar blights.
2. Develop effective methods to manage and determine the infectivity of aster leafhoppers.
3. Identify carrot varieties suitable for Michigan that are resistant to nematodes, plant diseases and insects.
4. Identify effective reduced-risk herbicides and develop alternative weed control methods.
5. Identify factors that contribute to culls such as soil quality, nematode populations, and soil-borne diseases.
6. Develop improved facilities and disease management strategies for storing fresh and processing carrots.
7. Develop precision agriculture techniques.

***Note:** Four grower attendees thought that the first two research priorities were of equal importance. One attendee thought that number three should be moved to position number two.

Regulatory:

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

- **$** Lorox and Fusilade are essential for weed control in commercial production; need registration of Prowl, Dual and Select as alternatives.
- **$** The broad spectrum fungicide Bravo 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.

Education:

- **$** Educate and provide technical support to growers and consultants as new materials and strategies are developed.
- **$** Continue IPM education and on-farm demonstration plots.
- **$** Educate growers and consumers regarding the risks and benefits of Genetically Enhanced Organisms.
- **$** Promote on-farm diagnostic tests for blight (microscopes and training needed).
- **$** Educate consumers on recent strides in integrated pest management and production practices.

BACKGROUND

Michigan ranks third nationally (after California and Washington) in fresh market carrot production (5,100 acres, valued at $21 million) and fifth nationally in the production of carrots for processing (1,700 acres, valued at $2 million). Carrot production in Michigan is localized primarily in the west central region in the sandy loam soils of Montcalm and Oceana counties. Significant production of carrots for the fresh market also occurs in Newaygo and Lapeer counties, where muck soils are common.

Michigan carrot 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 pesticides commonly used 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 Michigan carrot industry already has the challenge of producing carrots without certain pesticides. These growers produce carrots for the baby food industry. 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 including the use of pesticides. Following are the pests that are significant in Michigan carrot production.

Because high humidity and frequent rainfall or irrigation are 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. Diseases such as cavity spot (*Pythium* spp.) and crater rot (*Rhizoctonia carotae*) affect root quality and reduce

yield. The northern root knot (*Meloidogyne hapla*), carrot cyst (*Heterodera carotae*) 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 soil-borne pest infestations.

Aster yellows disease caused by a mycoplasma-like organism (MLO) transmitted by aster leafhoppers (*Macrosteles quadrilineatus*) results in distorted growth, fibrous and bitter tasting roots. Aster leafhoppers acquire the MLO 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 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 are 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 soil-borne 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 the application of insecticides after scouting and weed management.

Using current cultural practices, it would be very difficult to produce carrots profitably without the use of herbicides. In order to prevent erosion, which is a serious problem 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 crop. 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 control is with pre- and post-emergence herbicides.

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, the use of 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 education needs. Pests are presented in alphabetical order.

INSECTS

1. **Aster leafhopper (*Macrosteles 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.

   Organophosphate (OP) insecticides currently registered:

   Some processors restrict or prohibit the use of all OPs.

   - ! Malathion (Malathion)
   - B Used in rotation with other products for resistance management, although resistance is not a major concern with this product.
   - B Used from June to August; discontinued 3 weeks before harvest.
   - B Economic threshold depends on the percentage of leafhoppers carrying the pathogen and disease resistance of the carrot variety. Currently, there is not a timely and cost-effective way to test for the presence of the pathogen.

   Carbamate insecticides currently registered:

   Some processors restrict or prohibit use of carbamates.

   - ! Carbaryl (Sevin)
   - B 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. Currently, there is not a timely and cost-effective way to test for the presence of the pathogen.

! Methomyl (Lannate)

- Handler and applicator concerns.
- Cost is twice that of pyrethroids.
- Short residual.
- More effective than Asana in hot weather.

Other insecticides currently registered:

! Esfenvalerate (Asana)

- High use, high importance.
- Not effective in hot weather.

! Cyfluthrin (Baythroid)

- Relatively new (1999), not used much.
- Expensive: $1.30 more per acre than Asana, but better than Asana in hot weather.

! Endosulfan (Phaser, Thiodan)

- Some processors restrict or prohibit use, not used much.
- Only one application allowed per season.

Other pest management aids:

! Scouting

Pipeline pest management tools:

! None identified.

"To do" list for aster leafhopper:

Research needs:

! Identify movement of aster leafhoppers in relation to wild hosts of the pathogen, and sites for aster leafhopper reproduction, development, and overwintering.

! Develop inexpensive and timely method of sampling aster leafhopper populations to determine if pathogen is present.

! Screen carrot varieties suitable for Michigan=s needs for resistance to aster yellows.

! Determine efficacy and use patterns of reduced risk insecticides and biocontrol agents.

- Study the effects of nutrient supplementation on plant vigor and resistance to aster yellows.
- Determine feeding preference of aster leafhoppers on different carrot varieties.
- Determine the importance of fungi that attack aster leafhoppers.

Regulatory needs:

- Expedite registration for safe and effective alternatives.

Educational needs:

- Stress importance of weed control of non-crop host plants.
- Promote use of resistant or tolerant carrot varieties as information becomes available.
- Educate growers about association of aster leafhoppers and transmission of the aster yellows organism.
- As new management tools are available, provide training on use.

2. **Carrot weevil (*Listronotus oregonensis*)** – Carrot weevils are occasionally a problem especially in areas with limited or no crop rotation and 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.

Organophosphate insecticides currently registered:

- None

Carbamate insecticides currently registered:

- Oxamyl (Vydate) - registered for control of larvae
  - Application at planting may control a number of non-target pests.
  - Systemic activity with foliar uses also.
  - Post-plant application has a 24(c) registration.

Other insecticides currently registered:

- Esfenvalerate (Asana) - registered for control of adult weevils
  - Applications targeting aster leafhoppers may be providing control.
- Cyfluthrin (Baythroid) - registered for control of adult weevils
  - Applications targeting aster leafhoppers may be providing control.

Other pest management aids:

- Scouting.
- Biological control of carrot weevils by *Anaphes sordidatus* (an egg parasitoid).
- Rotation with crops other than celery.
- Control of broad leaf weeds in field borders, especially wild carrot and 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.

ATo do@ list for carrot weevil:

Research:

- Determine efficacy and use patterns of reduced risk insecticides and biocontrol agents including azadirachtin, imidacloprid, methoxyfenozide, spinosad, and thiamethoxam.
- Develop selective insecticides and pest monitoring programs to enhance the effectiveness of biological control agents.

Regulatory:

- Expedite registration for safe and effective alternatives.

Education:

- Emphasize cultural methods that aid insect management.
- As new management tools become available, provide training on use.

3. **Cutworms (Noctuidae)** - A sporadic pest, mostly a problem when a grass field is plowed down for carrot production.

Organophosphate insecticides currently registered:

- None

Carbamate insecticides currently registered:

- Methomyl (Lannate)
  - Very effective but expensive.
  - If pest is detected early, need only be applied to field edges.

Other insecticides currently registered:

- Esfenvalerate (Asana)

- Very effective and is preferred.
- Cyfluthrin (Baythroid)
- New in 2000, expensive ($1.30/acre more than Asana), but very effective.

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:

- Determine efficacy and use patterns of reduced risk insecticides and biocontrol agents including spinosad and methoxyfenozide.

Regulatory needs:

- If spinosad and methoxyfenozide are proven safe and effective, expedite registration.

Educational needs:

- As new management tools become available, provide training on use.
- Stress importance of weed-free fields and cultural practices that aid insect management.

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.

   Organophosphate insecticides currently registered:

   - Malathion (Malathion)
   - Diazinon (Diazinon)

   Carbamate insecticides currently registered:

   - None

   Other insecticides currently registered:

- Endosulfan (Phaser, Thiodan)

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:

- Determine efficacy and use patterns of reduced risk insecticides and biocontrol agents including imidicloprid and thiamethoxam.
- Develop selective insecticides and pest monitoring programs to enhance the effectiveness of biological control agents.

Regulatory needs:

- Expedite registration of safe and effective controls.

Education needs:

- As new management tools are available, provide training on use.

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 (*Meloidogyne hapla*)** - Wide host range, common problem on both muck and mineral soils.
2. **Carrot Cyst Nematode (*Heterodera carotae*)** -Extremely difficult to manage because it can persist in soil without a host for 10 years. Currently only known to exist in muck soils in Michigan where there has been a long history of carrot production.
3. **Penetrans Root Lesion Nematode (*Pratylenchus penetrans*)** - Problems are usually localized, but can be found throughout Michigan.
4. **Pin Nematode** - A sporadic pest. Two species are known to exist in Michigan.

Organophosphate nematicides currently registered:

- None

Carbamate nematicides currently registered:

- Oxamyl (Vydate)
  - Most effective when used in multiple applications at a low rate, not effective on carrot cyst.
  - Efficacy inconsistent among years and locations (no longer effective on some sites).
  - Registrant priority may be low.

B2 carcinogenic nematicides currently registered:

- 1,3-Dichloropropene (Telone II, Telone C-17, Telone C-35)(fumigant)
  - Requires specialized application equipment, higher rates required for carrot cyst.
  - Must be applied when temperatures exceed 50EF.
  - No longer effective on specific sites in Lapeer and Newaygo counties.
  - Expensive.
- Metam sodium (Vapam) (fumigant)
  - Applied as a chemigant (in irrigation water), environmental risks.
  - Ground driven applicators try to apply with too little water, do not get efficacy.
  - Soil temperature requirements make it exceptionally well suited to Michigan's cold soils.

Other pest management aids:

- Crop rotation (minimum of 3-4 years) with non-host crops such as corn, wheat, and rye (longer rotation required for carrot cyst).
- Sanitation including cleaning machinery and equipment between fields.
- Use of nematicidal crop such as marigolds in a rotation scheme.
- Green manure crops (i.e. oil seed, radish, sudax) need to be plowed down, avoid legumes (clovers, alfalfa and vetch) unless established for two or more years.

Pipeline pest management tools:

- None identified.

"To do" list for nematodes:

Research needs:

- Determine efficacy of biological control agents including *Bacillus thuringiensis*, Deny, and *Steinerenma carpocapse*.

- Determine effects of soil amendments such as crab meal, other chitinous materials, sewage sludge, certain green manures, sawdust and bonemeal.
- Develop precision agriculture technology to identify and treat problem areas.
- Breed and screen carrot varieties suitable for Michigan's needs for resistance.
- Develop safe and effective alternative nematicides and cultural practices.
- Identify uses for DiTera.
- Identify nematicidal plants.
- Determine the soil quality that minimizes nematode problems.
- Evaluate Mi gene.
- Determine safe and effective application rates of Telone II, Telone C-17 and Telone C-35.

Regulatory needs:

- Registration of at-plant use of Telone II.
- Registration of post-plant use of Vydate.
- Land swapping (Freedom to Farm USDA programs).

Education needs:

- Educate growers on safe and effective nematicides.

FUNGAL/BACTERIAL/MLO PATHOGENS

1. **Aster yellows -** See Aster Leafhopper

2. **Bacterial Blight (*Xanthomonas campestris* pv. *carotae*) -** Not endemic to area but may be introduced via seed.

   B2 carcinogenic pesticides currently registered:

   - None

   Other pesticides currently registered:

   - Copper hydroxide (Kocide, Champ)
   - Resistance is a concern.

   Other pest management aids:

   - *Xanthomonas*-indexed seed.
   - Scouting.

- Post-harvest tilling to speed breakdown of infected plant debris.
- Crop rotation (minimum 2 years).

Pipeline pest management tools:

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

"To do" list for bacterial blight:

Research needs:

- Screen carrot varieties suitable for Michigan=s needs for resistance.
- Develop rapid laboratory and on-farm diagnostic tests.
- Develop and test biocontrol agents.
- Conduct yearly surveys to document occurrence and severity.
- Determine bacterial threshold on seed that can be tolerated in Michigan without yield loss.

Regulatory needs:

- None identified.

Education needs:

- Educate growers on disease symptoms and identification.

3. Cavity spot (*Pythium* spp.)

B2 carcinogenic pesticides currently registered:

- Mefenoxam/chlorothalonil (Ridomil/Bravo) - not typically used

Other pesticides currently registered:

- Mefenoxam/copper hydroxide (Ridomil/Copper) - not typically used
- Mefenoxam at planting - used in heavily-infested fields

Other pest management aids:

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

Pipeline pest management tools:

- None identified.

"To do" list for cavity spot:

Research needs:

- Determine efficacy and use patterns of reduced-risk fungicides and biocontrol agents.
- Screen carrot varieties suitable for Michigan's needs for resistance.
- Determine the value of rotation, cover crops, mulch and compost amendments as management aids.
- Determine the value of ridging (water management) and zone tillage as management aids.
- Develop cultural techniques to reduce overwintering inoculum.
- Develop post-harvest disease management strategies.
- Develop a soil test to quantify pathogen levels.

Regulatory needs:

- None identified.

Education needs:

- Educate growers on disease symptoms and identification.
- Emphasize cultural and rotational methods that aid disease management.

4. Crater rot (*Rhizoctonia carotae*)

Chemical control currently registered:

- None

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 (0EC), relative humidity (<95%), and air circulation in storage facilities.
- Extended (>3 years) crop rotation with non-susceptible crops.

Pipeline pest management tools:

- None identified.

"To do" list for crater rot:

Research needs:

- Determine efficacy and use patterns of reduced-risk fungicides and biocontrol agents.
- Screen carrot varieties suitable for Michigan's needs for resistance.

- Determine the value of rotation and cover crops as management aids.
- Determine the role of field infection in disease development during storage.
- Develop a soil test to quantify pathogen levels.

Regulatory needs:

- None identified.

Education needs:

- Educate growers on disease symptoms and identification.
- Emphasize cultural and rotational methods that aid disease management.

5. Damping off (*Pythium* spp., *Rhizoctonia solani*); root forking, stubbing (*Pythium* spp., *Phytophthora* spp.)

B2 carcinogenic pesticides currently registered:

- None

Other pesticides currently registered:

- *Bacillus subtilus* GB03 (Kodiak) - seed treatment
- Fludioxonil (Maxim) - seed treatment
- Oxadixyl (Anchor)- seed treatment
- Mefenoxam (Apron XL LS, Ridomil Gold) - seed treatment, in-furrow treatment
- Metalaxyl (Apron FL, Apron 50W, Allegiance-FL) - seed treatment
- Thiram - seed treatment

Other pest management aids:

- Good soil drainage.
- Crop rotation with non-susceptible crops (>3 years).

Pipeline pest management tools:

- None identified.

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

Research needs:

- Determine efficacy and use patterns of reduced risk fungicides and biocontrol agents.
- Screen carrot varieties suitable for Michigan's needs for resistance.
- Determine the value of rotation and cover crops as disease management aids.
- Optimize fertilization program for enhanced early plant vigor and resistance.

- Determine the value of compost and other soil amendments in improving drainage and air circulation and enhancing disease management.

Regulatory needs:

- None identified.

Education needs:

- Educate growers on disease symptoms and identification.
- Emphasize cultural and rotational methods that aid disease management.

6. **Fungal leaf spots (*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 foliage 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:

- Chlorothalonil (Bravo) – field application only
- High importance, commonly used, cost effective.
- Iprodione (Rovral) - field application, 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:

- Copper hydroxide (Kocide, Champ)*
- Copper sulfate (Basicop)*
- Copper ammonium carbonate (Copper Count N)*

*Currently, copper-based fungicides alone do not control disease at a commercially acceptable level when pressure is significant.

Other pest management aids:

- Certified, tested and treated seed.
- Scouting.
- Post-harvest tilling to speed breakdown of infected plant debris.
- Crop rotation with non-susceptible crops (minimum of 2 years).

- Planting disease tolerant cultivars suitable for Michigan and targeted markets.

Pipeline pest management tools:

- Reduced risk fungicides not yet registered including Quadris, Flint, and Switch.
- Use of a disease forecasting program to time fungicide sprays.

"To Do" list for fungal leaf spot:

Research needs:

- Screen carrot varieties suitable for Michigan=s needs for resistance.
- Determine efficacy and use patterns of reduced risk fungicides and biocontrol agents.
- Optimize fertilization program for enhanced foliar vigor, blight resistance and late season foliage growth.
- Determine the efficacy of coppers used alone and alternated with strobilurins and other new chemistries.
- Develop resistance management programs for new products including Quadris, Flint, and Switch.
- Validate disease forecasting programs using currently registered and soon to be registered fungicides.
- Test weather monitoring equipment for reliability, consistency, and ease of use.
- Identify effective product suitable for use as a seed treatment.

Regulatory needs:

- 24(c) or Section 18 for reduced-risk fungicides such as Quadris, Flint and Switch.

Education needs:

- Emphasize the influence of weather on disease development.
- Train growers and consultants to use weather equipment and disease forecasting program.
- Disseminate information regarding disease predictions via computer, e-mail, and code-a-phone.
- Resistance management and use of new products.
- Educate growers on disease symptoms and identification.
- Emphasize the importance of selecting resistant or tolerant varieties as a disease management aid.

7. **Powdery mildew (*Erysiphe polygoni*)** - Not considered a significant problem.

   B2 carcinogenic pesticides currently registered:

   - None

   Other pesticides currently registered:

   - Sulfur (Kumulus, Microthiol Special, Thiolux)

   Other Pest Management Aids:

   - Scouting

   Pipeline pest management tools:

   - None identified.

   "To do" list for powdery mildew:

   Research needs:

   - Screen carrot varieties suitable for Michigan's needs for resistance.
   - Determine efficacy and use patterns of reduced risk fungicides and biocontrol agents.

   Regulatory needs:

   - None identified

   Education needs:

   - Educate growers on disease symptoms and identification.

8. **White mold (*Sclerotinia sclerotiorium*) -** Primarily a storage problem. Not considered a typical problem in the field.

   Carbamates currently registered:

   - Benomyl (Benlate) – not typically used

   Other fungicides currently registered:

   - None

   Other pest management aids:

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

   Pipeline pest management tools:

- None identified.

"To do" list for white mold:

Research needs:

- Determine efficacy and use patterns of reduced risk fungicides and biocontrol agents.
- Screen carrot varieties suitable for Michigan's needs for resistance.
- Determine the value of rotation and cover crops as disease management aids.

Regulatory needs:

- None identified.

Education needs:

- None identified.

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.

   Chemical controls currently registered:

   Pre-plant:

   - Glyphosate (Roundup)
     - 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.
     - Roundup Ready carrots is a political issue, but is considered possible.

   Pre-emergence:

   - Trifluralin (Treflan, Trilin) [C carcinogen]
     - 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 pre-plant incorporated.

- Kills cover crops.
- Groundwater issues.

Pre- and Post-emergence:

- Linuron (Lorox, Linex) [C carcinogen]
- Without Lorox, would not currently be able 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 resistance noted.
- Composites, wild carrot, and nutsedge not controlled; minimal preemergence grass control.

Post-emergence:

- Metribuzin (Sencor) [D carcinogen]
- May be substituted for one postemergence Lorox application in some situations.
- Effective on broadleaves; moderate control of Composites.
- Minimal weed control spectrum at labeled rates.
- Active at low rates, cost effective.
- Potential use on some resistant weeds, cross-resistance may be a problem.
- Injures carrots under some conditions.
- One application allowed and only at specific crop size (5-6 leaves).
- Cannot be applied during cloudy weather or when temperature >85EF.
- One manufacturer has dropped its registration.
- Fluazifop-P-butyl (Fusilade)
- Important grass herbicide, low rates used, cost effective.
- Very effective on annual grasses and cover crops.
- Low rates, cost effective.
- Minimal crop residues.

- Weak on quackgrass, no broadleaf activity or yellow nutsedge control.
- Potential resistance in some annual grasses.
- Risk cup is full (FQPA) and use on carrots may not be continued.

! Sethoxydim (Poast)

- 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.

! Clethodim (Select) - postemergence

- Effective on cover crops and annual grasses including those resistant to other herbicides.
- Weak on quackgrass, no broadleaf activity or yellow nutsedge control.
- Low rates, cost effective.
- Minimal crop residues.

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:

! S-metolachlor (Dual Magnum) – 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.

! Pendimethalin (Prowl) - preemergence

- Good on grass, kills cover crop under some environmental conditions.
- Very safe on carrot.

- Does not need incorporating.
- Has a yellow dye that turns everything yellow until first rainfall following application.
- Weak on common lambsquarters, ladysthumb, Composites and mustards.

! Flumioxazin (Valor) - preemergence and postemergence

- Very low rates can be used, appears to be safe environmentally, more research needed.
- No control of several grasses and a few broadleaves.
- May be expensive.

"To do" list for weeds:

Research needs:

! Determine the value of mulching and composting as weed management aids.

! Develop innovative mechanical weed control methods.

! Determine the efficacy of strip tillage with banded application of herbicides in managing weeds.

! Test new herbicides for crop safety and efficacy.

! Test effectiveness of fertilization programs to provide carrots a competitive advantage.

! Develop a mitigation strategy.

Regulatory needs:

! Need registration for Dual Magnum, Prowl, and Select.

! Potential label for flumioxazin and other new herbicides.

! In the registration process, minor uses need to be protected.

! Plant-back restrictions of some herbicides need to be reduced so growers can have increased flexibility in rotation programs.

Education needs:

! Production industry should be kept informed of potential changes in pesticide registration.

! As new management tools become available, promote training on use.

Table 1. Classification of Pesticides

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

Table 2. Registered Pesticides for Carrots in Michigan

Active ingredient	Trade name	Company
	FUNGICIDES/BACTERICIDES	
Bacillus subtilus GB03	Kodiak	Gustafson, L.L.C.
Benomyl	Benlate	DuPont Agricultural
Chlorothalonil	Bravo	Zeneca Ag Products
Copper compound (copper ammonium carbonate)	Copper Count N 8L	Mineral Research & Development Corp.
Copper compound (copper hydroxide)	Champ Kocide Nu-Cop	Agtrol International Griffin L.L.C. Micro Flo Company
Copper compound (copper sulfate)	Basicop	Griffin L.L.C.
Fludioxonil	Maxim 4FS	Novartis Crop Protection, Inc.
Iprodione	Rovral	Rhône-Poulenc Ag Company
Mefenoxam	Apron XL LS Ridomil Gold Ultra Flourish	Novartis Crop Protection, Inc. Novartis Crop Protection, Inc. Agtrol International
Mefenoxam/chlorothalonil	Ridomil Gold/Bravo	Novartis Crop Protection, Inc.
Mefenoxam/copper hydroxide	Ridomil Gold/Copper	Novartis Crop Protection, Inc.
Metalaxyl	Apron FL Apron 50W Allegiance-FL	Novartis Crop Protection, Inc. Gustafson, L.L.C. Gustafson, L.L.C.
Oxadixyl	Anchor	Gustafson, L.L.C.
Sulfur	Kumulus DF Microthiol Special Thiolux DF	BASF Corporation Elf Atochem North America, Inc. Sandoz
Thiram	Thiram	Gustafson, L.L.C.
	INSECTICIDES/NEMATICIDES	
1,3-Dichloropropene	Telone II	Dow AgroSciences
Cyfluthrin	Baythroid 2E	Bayer Corporation
Carbaryl	Sevin 80WSP	Rhône-Poulenc Ag Company
Diazinon	Diazinon 500AG	Novartis Crop Protection, Inc.
Endosulfan	Phaser 3EC	AgrEvo USA Company

Table 2. Registered Pesticides for Carrots in Michigan

Active ingredient	Trade name	Company
	Thiodan 3EC	FMC Corporation Ag Company
Esfenvalerate	Asana XL	DuPont Agricultural Products
Malathion	Malathion 57EC	United Agri Products
Metam-sodium	Busan 1020	Buckman
	Vapam	Zeneca Ag Products
Methomyl	Lannate SP	DuPont Agricultural Products
Oxamyl	Vydate L	DuPont Agricultural Products
	HERBICIDES	
Fluazifop-P-butyl	Fusilade	Zeneca Ag Products
Glyphosate	Roundup	Monsanto Company
Linuron	Linex, Lorox	Griffin L.L.C.
Metribuzin	Sencor	Bayer Corporation
Sethoxydim	Poast	BASF Corporation
Trifluralin	Treflan	Dow AgroSciences
	Trilin	Griffin L.L.C.

Table 3. Unregistered Fungicides Tested on Carrots in Michigan

Active ingredient	Trade name	Company
Azoxystrobin	Quadris	Zeneca Ag Products
Cyprodinil	Vangard	Novartis Crop Protection, Inc.
Fenbuconazole	Indar	Rohm and Haas Company
Kresoxim-methyl	Sovran	BASF Corporation Ag Products
Tebuconazole	Folicur	Bayer Corporation
Trifloxystrobin	Flint/CGA 279202	Novartis Crop Protection, Inc.
Trifloxystrobin + propiconazole	Stratego	Novartis Crop Protection, Inc.

Table 4. Description of Pests and Pathogens of Carrot

Pest/Pathogen	Symptoms
FUNGI/BACTERIA	
Alternaria leaf spot ..... (*Alternaria dauci*)	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, which can result in weak foliage or defoliation, making harvest impossible. Often occurs in association with *Cercospora* leaf spot.
Aster yellows	A disease caused by a mycoplasma-like organism, 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 ..... (*Xanthomonas campestris* pv. *carotae*)	Yellow-ringed dark spots 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.
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 marketable yields.
Cercospora leaf spot ..... (*Cercospora carotae*)	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 *Alternaria* leaf spot.
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.
Damping off ..... (*Pythium* spp., *Rhizoctonia solani*); Root forking, stubbing ..... (*Pythium* spp., *Phytophthora* 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.
Powdery mildew ..... (*Erysiphe polygoni*)	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.
White mold ..... (*Sclerotinia sclerotiorum)*	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/NEMATODES	
Carrot weevil	Adults lay eggs in leaf petioles and leave small circular feeding

Table 4. Description of Pests and Pathogens of Carrot

Pest/Pathogen	Symptoms
(*Listronotus oregonensis*)	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.
Carrot cyst nematode ..... (*Heterodera carotae*)	Roots become shallow and disfigured, and foliage becomes stunted, chlorotic and wilted by nematodes living in roots and injecting toxins while feeding, severely reducing yield.
Cutworms ..... (Noctuidae)	Larvae can cause severe petiole damage and defoliation.
Green peach aphids ..... (*Myzus persicae*)	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.
Leafhoppers ..... (*Macrosteles quadrilineatus*)	Adults and nymphs pierce the vascular tissues of the plant to extract sap. They vector aster yellows disease.
Northern root-knot nematode ..... (*Meloidogyne hapla*)	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	Pin nematodes can retard root growth and affect the development of orange pigment.
Root lesion nematode ..... (*Pratylenchus penetrans*)	Root lesion nematodes cause necrosis, discoloration, stunting and disfiguration by burrowing into the carrot root to feed.

Table 5. Advantages and Disadvantages of Pesticides for Carrot

Active ingredient	Disease/Pest	Advantages/Disadvantages
FUNGICIDES		
Bacillus subtilus GB03	Damping off	C Seed treatment. C Works best with a chemical seed treatment.
benomyl	White mold	C Efficacy depends on roots being in treated areas. C Some resistance has been reported. C Both preventive and eradicating fungicide, excellent residual activity, can control some nematodes. C Carbamate fungicide. C Not allowed by certain processors.
chlorothalonil	Alternaria leaf spot Cercospora leaf spot	C Broad spectrum foliar protectant fungicide. C Group B2 carcinogen. C Cost effective.
copper compounds	Alternaria leaf spot Cercospora leaf spot Bacterial blight	C Toxic to fish. C Limited efficacy under severe disease pressure. C Broad spectrum protectant fungicide and bactericide.
fludioxonil	Damping off	C Seed treatment. C Toxic to fish and aquatic invertebrates.
iprodione	Alternaria leaf spot	C Group B2 carcinogen. C Some systemic activity. C Expensive. C Important as a seed treatment.
mefenoxam	Damping off Root forking/stubbing	C Group E chemical, resistance concerns, corrosive. C Long lasting activity.
mefenoxam/ chlorothalonil	Cavity spot	C Mefenoxam: Group E chemical, resistance concerns, corrosive. C Long lasting activity. C Chlorothalonil: Broad spectrum foliage protectant fungicide, Group B2 carcinogen.
mefenoxam/ copper hydroxide	Cavity spot	C Mefenoxam: Group E chemical, resistance concerns, corrosive. C Long lasting activity. C Copper hydroxide: Toxic to fish.
metalaxyl	Damping off	C Seed treatment. C Group E chemical, resistance concerns, corrosive.

Table 5. Advantages and Disadvantages of Pesticides for Carrot

Active ingredient	Disease/Pest	Advantages/Disadvantages
		C Long lasting activity.
oxadixyl	Damping off	C Seed treatment. C Curative and eradicant properties.
sulfur	Rust	C Very safe chemical. C Effectiveness is related to the fineness of the particles.
thiram	Damping off	C Seed treatment. C Broad-spectrum, less expensive than alternatives.
UNREGISTERED FUNGICIDES		
azoxystrobin	Alternaria leaf spot Cercospora leaf spot	C Will likely be expensive. C Broad control spectrum. C Low application rates and intervals comparable to or longer than most alternatives. C Practically nontoxic to birds, mammals, honeybees. C Highly toxic to freshwater fish and invertebrates. C Risk of fungicide resistance.
cyprodinil	Alternaria leaf spot Cercospora leaf spot	C Will likely be expensive. C Practically non-toxic to birds, small mammals, bees, earthworms. C Moderately toxic to fish. C Very highly toxic to freshwater/marine invertebrates. C Risk of fungicide resistance.
fenbuconazole	Alternaria leaf spot	C Risk of fungicide resistance.
kresoxim-methyl	Alternaria leaf spot	C Will likely be expensive. C Data suggests it will have a tendency to accumulate in fish. C Risk of fungicide resistance.
tebuconazole	Alternaria leaf spot	C Risk of fungicide resistance.
trifloxystrobin	Alternaria leaf spot	C Will likely be expensive. C Not considered a risk to birds, mammals and honeybees because of low toxicity. C Highly toxic to fish and aquatic invertebrates but not expected to occur in concentrations high enough to be

Table 5. Advantages and Disadvantages of Pesticides for Carrot

Active ingredient	Disease/Pest	Advantages/Disadvantages
		risky. C Risk of fungicide resistance.
trifloxystrobin + propiconazole	Alternaria leaf spot	C Will likely be expensive. C Trifloxystrobin: Not considered a risk to birds, mammals and honeybees because of low toxicity. C Highly toxic to fish and aquatic invertebrates but not expected to occur in concentrations high enough to be risky. C Risk of fungicide resistance.
INSECTICIDES/NEMATICIDES		
1,3-dichloropropene	Nematodes	C Cannot use on heavy soil. C Particularly effective against cyst-forming and meadow nematodes, also helps control weeds and diseases. C Group B2 carcinogen.
carbaryl	Leafhoppers	C Toxic to beneficial insects. C Excessive use leads to aphid outbreak. C Very effective against chewing insects, fast acting. C Carbamate insecticide.
cyfluthrin	Carrot weevils Cutworms Leafhoppers	C Toxic to fish, not effective against sub-surface soil insects. C Very effective against chewing insects, fast acting. C Not as effective at high temperatures, can result in buildup of aphid populations.
diazinon	Aphids	C Toxic to bees and birds. C Long residual time, good efficacy. C Organophosphate pesticide.
endosulfan	Aphids Leafhoppers	C Relatively non-toxic to bees, highly toxic to fish, corrosive to iron. C Moderate efficacy.
esfenvalerate	Carrot weevils Cutworms Leafhoppers	C Toxic to mite and aphid predators. C High efficacy rate for control of leafhoppers. C Not as effective at high temperatures.
malathion	Aphids Leafhoppers	C Broad spectrum insecticide that is toxic to beneficial insects. C Expensive. C Low mammalian toxicity.

Table 5. Advantages and Disadvantages of Pesticides for Carrot

Active ingredient	Disease/Pest	Advantages/Disadvantages
		C Organophosphate pesticide.
metam-sodium	Nematodes	C Very expensive. C Highly efficient. C Controls bacteria, fungi, weeds and soil insects. C Group B2 carcinogen.
methomyl	Cutworms Leafhoppers	C Toxic to bees, birds and fish. C Moderate efficacy, fast acting. C Carbamate insecticide.
oxamyl	Carrot weevils Nematodes	C Systemic insecticide that translocates downward. C Moderate efficacy. C Carbamate pesticide.
HERBICIDES		
fluazifop-P-butyl	Grasses	C Broadleaf crops are tolerant, higher rate needed on quackgrass. C Limit 6 pt/A/year.
glyphosate	Annual grasses, Broadleaf weeds	C Excellent efficacy, non-residual. C Can control dense stands of perennials other herbicides cannot. C Slightly toxic to birds, practically nontoxic to fish, aquatics, honeybees. C Group E chemical.
linuron	Annual grasses, broadleaf weeds	C Not effective on perennial weeds. C Can harm young seedlings. C Cannot apply at temperatures $85EF and pressures $40 psi. C Weeds of Compositae family beginning to show resistance. C Very effective on muck soils. C Minimal risk to honeybees. C Chronic risk to birds. C Chronic effects in wild mammals likely. C Group C carcinogen.
metribuzin	Broadleaf weeds	C Good efficacy, control lasts 3-4 months. C Higher rates needed on soils with high organic matter. C Do not apply during cloudy weather or when temperature >85EF. C Relative inexpensive.

Table 5. Advantages and Disadvantages of Pesticides for Carrot

Active ingredient	Disease/Pest	Advantages/Disadvantages
		C Can cause phytotoxicity. C Group D carcinogen.
sethoxydim	Grasses	C Selective for emerged grasses. C Not effective at temperatures <60EF. C Established grasses may need two applications.
trifluralin	Annual grasses, broadleaf weeds	C Good grass control. C Kills weed seeds as they germinate. C Rainfall not required. C Must incorporate into soil within 24 hours for best effectiveness. C Not very effective on muck soils. C Group C carcinogen.

Table 6. Efficacy Ratings of Pest Management Tools for Control of Diseases of Carrot

Management tool	Diseases of carrots[1]								
	ALS	AY	BB	CS	CLS	CR	DO/ RFS	PM	WM
Carbamates registered in MI									
benomyl (Benlate)	B[2]	B	B	B	B	B	B	B	P
B2 carcinogen fungicides registered in MI									
chlorothalonil (Bravo)	G-E	B	B	B	G-E	B	B	B	B
1,3-dichloropropene (Telone C-17) (fumigant)	B	B	B	G?	B	?	?	B	?
iprodione (Rovral)	G-E	B	B	B	G-E	B	B	B	B
mefenoxam [E chemical]/chlorothalonil (Ridomil Gold)	B	B	B	NR	B	B	B	B	B
metam sodium (Vapam) (fumigant)	B	B	B	G	B	?	?	B	?
Other fungicides registered in MI									
copper compounds (Champ, Kocide, Nu-Cop, Basicop)	P-F?	B	?	B	P-F?	B	B	B	B
fludioxonil (Maxim 4FS)	B	B	B	B	B	B	F?	B	B
mefenoxam (Apron XL LS, Ridomil Gold)	B	B	B	B	B	B	F?	B	B
mefenoxam [E chemical]/copper hydroxide (Ridomil Gold/Copper)	B	B	B	NR	B	B	B	B	B
metalaxyl [E chemical](Apron FL, Apron 50W, Allegiance-FL)	B	B	B	B	B	B	F?	B	B
oxadixyl (Anchor)	B	B	B	B	B	B	F?	B	B

Table 6. Efficacy Ratings of Pest Management Tools for Control of Diseases of Carrot

Management tool	Diseases of carrots[1]								
	ALS	AY	BB	CS	CLS	CR	DO/ RFS	PM	WM
sulfur (Kumulus, Microthiol Special, Thiolux)	B	B	B	B	B	B	B	F?	B
thiram (Thiram)	B	B	B	B	B	B	F?	B	B
Products tested but not registered in MI									
azoxystrobin (Quadris)	E	B	B	B	E	B	B	B	B
cyprodinil (Vangard)	G-E	B	B	B	?	B	B	B	B
fenbuconazole [C carcinogen](Indar)	E	B	B	B	F	B	B	B	B
kresoxim-methyl (Sovran)	E	B	B	B	ND	B	B	B	B
tebuconazole [C carcinogen](Folicur)	E	B	B	B	F	B	B	B	B
trifloxystrobin (Flint)	E	B	B	B	?	B	B	B	B
trifloxystrobin + propiconazole [C carcinogen](Stratego)	E	B	B	B	?	B	B	B	B
Cultural controls/Biocontrol agents									
Bacillus subtilus GB03 (Kodiak)	B	B	B	B	B	B	?	B	B
Bacillus subtilus QST713 (Serenade)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Burkholderia cepacia Wis. J82 (Blue Circle)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Crop Rotation	P	P	P	P?	P	P?	P?	P	P?
Disease free seed	NF	B	NF	B	B	B	B	B	B
Early Planting	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND	NF-ND

Table 6. Efficacy Ratings of Pest Management Tools for Control of Diseases of Carrot

Management tool	Diseases of carrots[1]								
	ALS	AY	BB	CS	CLS	CR	DO/ RFS	PM	WM
Natural enemies (*Ampelomyces quisqualis*)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Plant correct soil temp	**B**	**B**	**B**	NF	**B**	NF	NF	**B**	**B**
Post-harvest tilling	P	P	P	P	P	P	P	P	P
Regulate soil moisture, leaf wetness	NF	NF	NF	NF	NF	NF	NF	NF	NF
Remove infected plants	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
Xanthomonas-indexed seed	**B**	**B**	NF	**B**	**B**	**B**	**B**	**B**	**B**

[1]Disease abbreviations: ALS = Alternaria leaf spot, AY = aster yellows, BB = bacterial blight, CS = cavity spot, CLS = Cercospora leaf spot, CR = crater rot, DO/RFS = damping off/root forking and stubbing, PM = powdery mildew, WM = white mold.

[2]Efficacy 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, **B** = 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 Ratings of Pest Management Tools for Control of Insects and Nematodes

Management tool	Insects and nematodes of carrots[1]							
	CW	CCN	C	GPA	LH	NRKN	PN	RLN
Carbamates registered in MI								
carbaryl (Sevin)	B[2]	B	B	B	E	B	B	B
methomyl (Lannate)	B	B	G	B	E	B	B	B
oxamyl (Vydate)	G	P-E	B	B	B	P-E	B	P-E
Organophosphates registered in MI								
diazinon (Diazinon)	B	B	B	G	B	B	B	B
malathion (Malathion)	B	B	B	G	G	B	B	B
B2 carcinogen insecticides and nematicides registered in								
1,3-dichloropropene (Telone)	B	G-E	B	B	B	G-E	B	G-E
metham sodium (Busan, Vapam)	B	G-E	B	B	B	E	B	E
Other insecticides and nematicides registered								
cyfluthrin (Baythroid)	E	B	E	B	E	B	B	B
endosulfan (Phaser, Thiodan)	B	B	B	G		B	B	B
esfenvalerate (Asana)	E	B	E	B	E	B	B	
Products currently under testing, not yet								
azadirachtin (Neemix)	B	B	?	B	?	B	B	B
DiTerra (biopesticide)	B	?	B	B	B	?	ND	?
imidacloprid (Provado)	B	B	B	B	F-G ?	B	B	B
methoxyfenozide (Intrepid or Runner)	ND	ND	G?	ND	?	ND	ND	ND
spinosad (Spintor)	ND	ND	G?	ND	?	ND	ND	ND
thiamethoxam (Actara)	ND	ND	ND	ND	G?	ND	ND	ND

Table 7. Efficacy Ratings of Pest Management Tools for Control of Insects and Nematodes

Management tool	Insects and nematodes of carrots[1]							
	CW	CCN	C	GPA	LH	NRKN	PN	RLN
Other pest management aids								
Cover Crops (Oil Seed Radish, Marigolds)	B	?	B	B	B	?	?	?
Crop Rotation	G	F-G	?	B	P	G-E	?	NF
Early Planting	B	B	B	B	NF	B	B	B
Field Selection	?	?	E	?	?	?	?	?
Natural Enemies (Biocontrols, Deny and Entomapathogenic Nematodes)	B	?	?	B	B	?	B	?
Removal of Infected Plants	NF	NF	NF	NF	NF	NF	NF	NF
Sanitation	B	?*	B	B	B	?*	?*	?*
Trap Crops	ND	B	ND	ND	?	B	B	B
Varietal Selection	ND	ND	ND	ND	?	ND	ND	ND
Weed Control	?	B	?	?	?	B	B	B

[1]Pest 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.

[2]Efficacy 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, **B** = 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 Ratings of Pest Management Tools for Control of Weeds in Carrot Production

Management tool	Weeds of carrots[1]															
	BA	LC	BG	FS	FP	CL	CP	LT	RP	CR	SD	MT	WC	YN	PW	CG
Registered herbicides																
fluazifop-p-butyl (Fusillade)	E [2]	G*	E	E	G	P	P	P	P	P	P	P	P	P	P	P
glyphosate [E chemical] (Roundup)	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
linuron [C carcinogen](Linex, Lorox)	B	F	G	F	F	E	G*	G	F-G	F	P	F	P	P	F	P
metribuzin [D carcinogen]	B	F	G	F-P	F	E	G	G	F-G	F-G	B	F	P	P	F	F
sethoxydim (Poast)	E	G*	E	E	G	P	P	P	P	P	P	P	P	P	P	P
trifluralin [C carcinogen]	B	G	G	F	G	G	G	F	G	P	P	P	P	P	P	P
Products not yet registered																
clethodim (Select)	E	E	E	E	G	P	P	P	P	P	P	P	P	P	P	P
flumioxazin (Valor)	B	G	G	F	F	G	G	G	G	G	P	G	P	P	F	F
s-metolachlor (Dual Magnum)	B	G	G	F	P	F	F	F	G	F	P	P	P	G	F	F
pendimethalin (Prowl)	B	G	E	G	F	G	F	F	F	F	F	F	P	P	F	F
Other pest management aids																
Cultivation	B	G	G	G	G	G	G	G	G	G	P	G	G	P	G	G
Mulching/Composting	B	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Rotation	B	G	G	G	G	P	G	G	P	G	G	P	G	P	P	P

[1]Weed abbreviations key: BA = barley, LC = large crabgrass, BG = barnyardgrass, FS = field sandbur, FP = fall panicum, CL = common lambsquarters, CP = common purslane, LT = lathsthumb, RP = redroot pigweed, CR = common ragweed, SD = swamp dodder, MT = marestail, WC = wild carrot, YN = yellow nutsedge, PW = pineappleweed, CG = common groundsel.

[2]Efficacy 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, **B** = not applicable, not used and/or not suspected of being efficacious, NR = registered for use, but not recommended

*Some resistance has been seen.