PEST MANAGEMENT IN THE FUTURE

A Strategic Plan for the Michigan Celery Industry

Prepared by:
Dr. Mary K. Hausbeck
Department of Plant Pathology
107 Center for Integrated Plant Systems
Michigan State University
East Lansing, MI 48824-1311
517-355-4534
hausbec1@msu.edu
March 2, 2011

Table of Contents

PREVIOUS PEST MANAGEMENT STRATEGIC PLAN

The previous Pest Management Strategic Plan (PMSP) workshop was conducted to document the pest management needs of Michigan's celery industry and to help address the industry's pesticide use issues. The previous celery PMSP workshop was held at Michigan State University in East Lansing, MI on January 28-29, 2002. Prior to the 2002 workshop, pest management strategies were heavily reliant on pesticide applications (up to 35 sprays per crop) and options for pesticide use were limited. Additionally, the EPA prohibited the use of mancozeb and benomyl, which were primarily used to manage foliar blights. Alternative chemicals for managing these diseases were either carcinogenic (chlorothalonil) or at risk of pathogen resistance (azoxystrobin and propiconazole). Insect control primarily relied on the use of organophosphate and carbamate pesticides, which pose health risks because they disrupt neurochemical processes. Additionally, many pesticide labels were not listed for use in greenhouses and presented a significant management hurdle since greenhouse production is necessary to start celery crops in Michigan. Research into alternative management strategies (pesticides, disease predictor models, and disease resistant cultivars) was requested to reduce pesticide resistance and environmental risks posed by management practices prior to 2002.

OUTCOMES

The following section describes the progress completed for the critical priorities from the 2002 PMSP workshop. Those priorities that are no longer listed as critical needs are indicated with *.

Research Priority: Develop a rapid diagnostic tool to determine aster leafhopper infectivity rates for use in combination with economic thresholds to trigger control measures. A new diagnostic test to determine the level of infectivity in aster leafhopper was developed using PCR techniques. This new method has been adopted on a limited basis by the carrot and celery industry. Logistics of sending the samples in for testing has a significant time lag in getting results back to growers. Growers feel that work still needs to be done in this area to shorten the time that results are made available to them.

Research Priority: Breed for resistance to *Fusarium* and other diseases. The reduction of commercial seed companies has put the availability of Michigan suitable celery varieties at risk. Michigan growers feel that local celery variety development is essential for the success of their industry. Breeding disease resistance into the current celery varieties is still a high priority. Cultivar germplasm developed by Michigan State University that is tolerant to *Fusarium* has been released to the commercial breeders but little has been done to develop these cultivars into new lines.

***Research Priority: Evaluate the fungicides Quadris and Tilt for possible growth regulator effects.** Quadris is now labeled for use on celery and its use has been widely adapted by Michigan celery growers with no reduction in yield. Research also showed that yield loss didn't occur with the use of Quadris, Tilt, or any of the newly developed fungicides.

Research Priority: Evaluate biopesticides, induced-resistance products, and other currently unregistered products for efficacy against *Fusarium* and other diseases. Testing of new products has continued since the PMSP was developed in 2002 with many new products showing good activity on foliar diseases of celery. Work will continue each year to determine rate response and crop safety of newly developed fungicides. Products effective for Fusarium control have not been developed.

***Research Priority: Develop disease predictor models for foliar blights.** Research into the use of TOM-CAST disease forecaster was conducted during 2003-2005 with some positive results. The forecaster did accurately predict when sprays should be applied but the threshold needed for adequate disease control didn't lengthen the spray interval past 7 days. The TOM-CAST forecaster also didn't impact the level of other diseases such as *Rhizoctonia* stalk rot.

***Research Priority: Evaluate trap crops and other alternatives for nematode management.** Research has shown that particular varieties of oil seed radish are better suited as a trap crop for nematodes. Growers have implemented the use of oil seed radish for both nematode control and uptake of residual fertilizer.

***Research Priority: Evaluate control measures in the greenhouse, including the use of fungicides, insecticides and cultural methods, with regard to their impact on disease and pest suppression in the field.** Products have been tested in the greenhouse for the control of root rot diseases. Products that are registered for use in the greenhouse have been compiled on a list for grower's use for early disease control. The use of cover crops has been researched with growers utilizing results and implementing the findings on fall plantings of mustards and oil seed radish.

Research Priority: Conduct herbicide resistance studies on groundsel and other weeds to find alternatives for their control. Several field tests were conducted which found no evidence of common groundsel resistance to Caparol (prometryn). Though groundsel is inhibited by Caparol applications, research observations indicate that groundsel is quicker to recover from this pesticide than other weed species. Research conducted at Michigan State University has helped secure a label for Chateau (flumioxazin), which has demonstrated a very good efficacy at controlling annuals and composites. Growers have expressed interest in the continuance of weed resistance studies.

Regulatory Priority: **Retention of specific pesticides for pathogens, insects, nematodes, and weeds.** Chlorothalonil, methomyl, oxamyl, acephate, permethrin, metolachlor, linuron, and prometryn are all still listed for use in celery. They remain an important part of the pest management process and their retention is still desired by growers.

***Regulatory Priority**: **Clarification is needed on pesticide labels for greenhouse use.** A list of products has been developed that can be used in the greenhouse for pest control. Restrictions are now listed on pesticide labels for those chemicals that cannot be used within the greenhouse.

Education Priorities: Each year research results were presented at both the Great Lakes Expo celery educational session and again at the yearly meeting with Michigan Celery Research Board. Forecasting and cover crop work were conducted on grower cooperator farms and field days highlighted variety development work conducted by Michigan State University. Professor Andrew Landers from Cornell presented his work on optimizing spray coverage for vegetable crops at the Expo celery educational session.

2011 WORKSHOP PARTICIPANTS

Michael Bauer	Eding Brothers Farm
George Bird,	Michigan State University Entomology Department
Greg Bouwkamp	Bouwkamp Farms
Bill Bouwkamp	Bouwkamp Farms
Mark Cnossen	Cnossen Farms
Brian Cortright	Michigan State University, Plant Pathology Department
Norm DeYoung	DeYoung Celery Farms
Jeff Eding	Eding Brothers Farm
Mary Hausbeck	Michigan State University, Plant Pathology Department
Lynae Jess	Michigan State University Extension
Bruce Klamer	V & W Farms
Gregg Krikke	K & V Celery
Jarrod Morrice	Michigan State University, Plant Pathology Department
Norm Myers	Michigan State University Extension
Mathieu Ngouajio	Michigan State University, Horticulture Department
Tim Riley	Wilbur-Ellis Co.
Lina Rodriguez	Michigan State University, Plant Pathology Department
Eric Schreur	Schreur Farms
Bruce Schreur	Schreur Farms
Al Steenwyk	C. Steenwyk and Sons
Bill Steenwyk	Michigan State University Extension
Roger Steenwyk	C. Steenwyk and Sons
Zsofia Szendrei	Michigan State University, Entomology Department
Bruce VanSolkema	Gun Lake Farms
Brian Verhougstraete	Michigan Department of Agriculture
Bernard Zandstra	Michigan State University, Horticulture Department

TOP PRIORITIES OF CELERY PRODUCTION

Research:

1. Development of varieties for Michigan growers that have resistance to *Fusarium* and other diseases. Resistance breeding should also consider horticultural traits such as petiole height and diameter.
2. Research the biology and management of *Colletotrichum*.

- Evaluate control measures for *Pythium* damping off, aphids, leafhopper, and tarnished plant bug in the greenhouse.
- Develop *Fusarium* management strategies.
- Develop management strategies for common purslane and other weeds (especially those resistant to herbicides).
- Screen selective insecticides for use in insect management (endosulfan replacement).
- Evaluate the interaction of aster leafhopper and aster yellows infection.
- Develop aphid management strategies. (Evaluate the impact of biological control agents under selective insecticide aphid management programs. Conduct a comparative evaluation of insecticides for aphid control.)

Regulatory:

1. Celery growers have a limited selection of products, making it difficult to manage resistance in diseases, insects, nematodes and weeds. In order for Michigan celery growers to remain competitive and produce a quality product, it is imperative that the following pesticides be retained:
   a. Fungicide: Bravo (chlorothalonil - broad spectrum, cost effective: nothing currently available compares with its efficacy). This product is important for resistance management.
   b. Insecticides: Lannate (methomyl - broad spectrum, cost effective), Orthene (acephate - systemic, broad spectrum), Ambush/Pounce (permethrin - broad spectrum, fast acting, short PHI).
   c. Nematicides: Vydate (oxamyl – important for nematode control and only product registered for carrot weevil).
   d. Herbicides: Dual Magnum (metolachlor - suppresses nutsedge and annual grasses), Lorox (linuron) and Caparol (prometryn) (both are broad-spectrum and are versatile with pre- and post-emergence use).
2. For the reasons stated previously, it is important that registration of the following products be expedited:
   a. Oberon; develop data for use as a miticide and partner with IR-4 to speed registration.
   b. Metaldehyde; partner with IR-4 to check tolerances.

Education:

- Emphasize a sustainable whole systems approach for pest management that includes scouting and IPM.
- As new products and methods become available, alert the industry of any effects they may have on the crop with regard to interactions in the field and in tank mixes.

- Demonstration and education regarding optimum spray patterns, drying times, environmental conditions and use of equipment in pesticide application to maximize efficacy of pest management.
- Expand information available about the biology and potential significance of nematodes as pests in Michigan.
- Notification of products that are coming up for re-registration and timing of their comment period.
- The effect of soil fertility management and cultural management practices on pest severity.

BACKGROUND

Michigan ranks second nationally (4.9% of total national production) after California in celery (*Apium graveolens* L.) production [1]. In 2010, approximately 2,000 acres were planted and 1,900 acres were harvested for a crop value of $17.8 million [1]. The majority of Michigan celery (60%) is packed for fresh market as full sized stalks, of which 15% are packed as hearts grown for specialty markets [2]. The remaining 40% is processed in frozen foods, soups, juice blends and other products [2]. Average yields of celery grown for the fresh market range from around 25 tons per acre up to 40 to 45 tons per acre for celery grown for processing. The majority of celery production in Michigan occurs on the southwest side along Lake Michigan (Newaygo, Oceana, Muskegon, Ottawa, Kent, Allegan, and Van Buren counties), but there is also some scattered production elsewhere in the state.

Celery seed is small and difficult to germinate, thus all commercial celery is planted from greenhouse-grown transplants that are produced in plug trays using peat-based media. Seeds are sown in early February in greenhouses and are ready for transplanting to the field in about eight weeks. Transplanting begins in April and ends in late July. Once celery reaches marketable size, there is a narrow window of opportunity for harvesting (about 6 to 8 days) before a significant reduction in quality occurs. Therefore, planting is scheduled so that a uniform quantity of celery is ready to harvest every week. Using transplants as opposed to direct seeding ensures uniform stands and faster maturing crops.

Celery is a cool season biennial that germinates well between 50° to 70°F (10° to 21°C) and grows best between 60° to 80°F (16° to 27°C) [2]. However, celery is sensitive to both high and low temperature extremes. Although young transplants can tolerate minor freezes, bolting may occur if temperatures drop below 55°F for 7 days or longer [2], which slows growth while flower stalks form, rendering the crop unmarketable. Damage on mature celery characteristic of freezing includes split petioles, again, making the stalks unmarketable. On the other hand, under high temperatures and moist conditions, the crop is more susceptible to disease and insect damage, as well as physiological problems.

Traditionally, celery has been grown on muck soils in Michigan, but can be grown on course textured mineral soils. Regardless of soil type, high fertility and moisture are necessary for tender succulent stalks. Overhead sprinkler or drip irrigation is used to apply water and fertilizer frequently to the shallow-rooted crop. If the soil is allowed to get too dry, physiological disorders such as blackheart, a calcium deficiency, will develop. Crop rotation with such commodities as onions or corn is practiced whenever possible to avoid a buildup of pests in the soil. At the end of the season, a winter cover crop of barley or rye is often planted to reduce erosion and add active organic matter to the soil.

Fresh market and processing celery grown in Michigan is harvested mechanically. Fresh market celery is trimmed, sized, washed and packed into 50-pound cartons at on-farm packing sheds. Growers transport the packed celery to shippers where it is cooled and placed into cold storage for shipment.

The most important insect and related pests of celery in Michigan are aphids (*Aphis fabae*, *Myzus persicae*, *Aphis helianthi*; Hemiptera Aphididae), aster leafhopper (*Macrosteles quadrilineatus*; Hemiptera: Cicadellidae), the tarnished plant bug (*Lygus lineolaris*; Hemiptera: Miridae), and cutworms (Lepidoptera: Noctuidae). Carrot weevil larvae (*Listronotus oregonensis*; Coleoptera: Curculionidae), loopers (*Anagrapha falcifera*, *Trichoplusia ni*; Lepidoptera: Noctuidae), and spider mites (*Tetranychus urticae*; Acari: Tetranychidae) are minor

or occasional pests. Vegetable leafminers (*Liriomyza sativae*; Diptera: Agromyzidae), celery leaftier (*Udea rubigalis*), wireworms (Elateridae), and slugs may occasionally be seen with sporadic economic damage.

Plant parasitic nematodes are microscopic roundworms found in soils, which primarily attack plant roots. General symptoms of nematode damage include stunting, premature wilting, leaf yellowing, and related symptoms characteristic of nutrient deficiencies. Stunting and poor stand development tends to occur in patches throughout the field as a result of the irregular distribution of nematodes in the soil. The northern root-knot (*Meloidogyne hapla*) and pin (*Paratylenchus hamatus*) nematodes are the main nematode pests of celery in Michigan. Occasionally root-lesion (*Pratylenchus penetrans*) and needle (*Longidorus elongatus*) nematodes are also seen.

The most important diseases affecting celery in Michigan are bacterial blight (*Pseudomonas syringae* pv. *apii*), foliar leaf blights (*Cercospera apii* and *Septoria apiicola*), *Fusarium* yellows (*F. oxysporum* f. sp. *apii*), and aster yellows (MLO). Soft rot (*Erwinia carotovora*), crater rot (*Rhizoctonia solani*), and damping off (*Pythium* spp. and *Rhizoctonia solani*) are occasionally a problem depending on season and location. White or pink mold (*Sclerotinia sclerotium*) and heart mosaic virus are minor diseases on celery in the state.

An additional disease, anthracnose (*Colletotrichum acutatum*), was identified in Michigan celery production fields during the 2010 growing season [3]. Growers reported extensive leaf curling and distortion within the petioles. Although the symptoms were similar to aster yellows, many plants retained their green coloration. Lesions and cracking were also noticed along the petiole, reducing the chances that the celery could be accepted for fresh-market sale. Anthracnose has not been confirmed within Michigan celery fields in the past and little is known about the susceptibility and control of the disease on different celery cultivars in Michigan. For a detailed description of this and the other pests listed above, please refer to Table 3.

Weeds compete with crops for moisture, nutrients, light, and space and can interfere with harvest operations. Additionally, many weed species serve as alternate hosts for common celery pests such as aster leafhoppers as well as plant pathogens and nematodes. Since weeds can also provide shelter and food for natural enemies of celery pests, weed management strategies should adequately address the positive and negative roles of weeds in and around the celery field. Adequate management of weeds in celery is particularly important early in crop growth. Weed competition during the first four weeks after transplanting will cause significant reductions in harvest quality.

Resistance management depends upon two key points: the ability to rotate applications of products with different modes-of-action and the ability to rotate between broad-spectrum and target-specific products. Newer products on the market tend to fall under the category of target-specific action, while older products generally tend to be broad-spectrum products. Celery growers already have a limited choice of products, which means that their ability to manage pesticide resistance becomes increasingly difficult as their choices for rotation narrow. Some products stand alone in their ability to combat certain pests. Loss of the pesticides listed under the top priorities is a major concern for Michigan celery growers who want to remain competitive and produce a quality product.

OUTLINE OF PLAN

Following is a pest by pest analysis of the current role of pesticides registered for use in celery production and sorted according to several major chemical classes. Organophosphates and carbamates are emphasized at the top of each chemical list because of their neurological activity. Chemicals with demonstrated and potential carcinogenic effects are identified at the end of each entry for a chemical. Other pest management tools (chemical, cultural and otherwise) that offer some control or are important in pest resistance management, but are not "stand alone" tools, are also discussed. For each product the efficacy is also listed according the following scale: E = excellent (98-100% control), VG= very good (90-98% control), G = good (85-90% control), F = fair (80-85%), P = poor (<80% control), NA = no data available, NC = no control, using this management method may increase problems with this pest. In some instances, products that have been identified as effective through preliminary research, but are currently unavailable for use on celery, are discussed under the heading "pipeline pest management tools." Immediately following each pest analysis is a "to do" list of research, regulatory, and education needs.

INSECT PESTS

1. **Aphids (green peach aphid *Myzus persicae*, sunflower aphid *Aphis helianthi*, black bean aphid *Aphis fabae*) –** Aphids are one of the most important insects damaging celery. Aphids become a major problem late in the season after repeated use of broad-spectrum insecticides. Earlier in the year, aphids may appear as pests in the greenhouse. Scouting is used to determine if and when control measures are needed. In the field, control measures are taken when 3% of plants are infested before leaf curling is noted or if there are more than 6 aphids/100 sweeps. Aphid control is especially important close to harvest because aphids found in a load will result in rejection of the celery. For this reason, insecticides with a short pre-harvest interval (PHI) are desired. Another issue with aphids is their ability to vector some viral pathogens; weeds can act as alternate hosts for aphids and viruses. Aphids easily develop resistance to insecticides, especially broad-spectrum insecticides such as pyrethroids, neonicotinoids, and organophosphates.

   Organophosphate insecticides currently registered:
   - acephate (Acephate 97 UP, Orthene 97)
     - Efficacy- G. PHI = 21 days prohibits its use at harvest, can only be used when celery is young, and only two applications per year are allowed. Widely used among growers. Toxic to birds and bees. Classified by EPA as a C carcinogen.
   - dimethoate (Dimethoate 2.67 EC, Dimethoate 4 EC, Dimethoate 4E)
     - Efficacy – F. PHI = 7. Labeled for leaf miner but is also effective at controlling aphids. Toxic to wildlife, aquatic invertebrates, and bees. May easily contaminate ground water. Classified by EPA as a C carcinogen.
   - malathion (Malathion 5, Malathion 5 EC, Malathion 57 EC, Malathion 8)
     - Efficacy- NA. PHI = 7 days. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Toxic to bees, birds, fish, amphibians, and other aquatic organisms. Classified by EPA as a D carcinogen.

Carbamate insecticides currently registered:

- methomyl (Lannate)
  - Efficacy- G. PHI = 7 days. Aphids are not listed on the label under celery but are listed under other crop types. Toxic to bees, mammals, aquatic invertebrates, and fish. High potential for contaminating ground water. Restricted use pesticide. Do not apply more than 24 pints/acre crop/season. Do not make more than 10 applications/season. Classified by EPA as an E chemical.

Neonicotinoid insecticides currently registered:

- acetamiprid (Assail 30 SG)
  - Efficacy- G. PHI = 7 days. Toxic to bees and wildlife. Reduced risk pesticide. Organophosphate replacement.
- clothianidin (Belay)
  - Efficacy- NA. PHI = 21 days. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Toxic to bees and aquatic invertebrates and may easily contaminate ground water.
- dinotefuran (Scorpion 35SL, Venom, Venom 20 SG)
  - Efficacy- NA. PHI = 7 days (foliar treatments; Scorpion and Venom); 21 days (soil treatment; Venom). Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. High potential for contaminating ground water. Reduced risk pesticide. Keep minimum 7 days between applications.
- imidacloprid (Admire Pro, Nuprid 2F, Alias many additional generic brands)
  - Efficacy- G. PHI = 45 days. Toxic to bees and may easily contaminate ground water. Classified by EPA as an E chemical.
- thiamethoxam (Platinum, Platinum 75 SG, Actara)
  - Efficacy- G. PHI = 7 days (foliar treatment; Actara); 30 days (soil treatment; Platinum). Also controls leaf hoppers. Toxic to bees, wildlife, and aquatic invertebrates. High potential for contaminating ground water.
- thiamethoxam/chlorantraniliprole (Voliam Flexi, Durivo)
  - Efficacy- G. PHI = 7 days (foliar treatment; Voliam Flexi); 30 days (soil treatment; Durivo). Expensive to use. Also controls cabbage loopers and leafhoppers. Toxic to bees, birds, oyster, shrimp, and wildlife. High potential for contaminating ground water.

Pyrethroid insecticides currently registered:

- permethrin (Perm-UP 25DF, Perm-UP 3.2 EC, Pounce 25 WP)
  - Efficacy- P. PHI = 1 day. Aphids are not listed on the label under celery but are listed under other crop types. May reduce beneficial insect populations, which could increase aphid populations. Toxic to bees, fish, and aquatic invertebrates. Restricted use pesticide. Classified by EPA as a B2 carcinogen.
- pyrethrin/piperonyl butoxide (Pyrenone)
  - Efficacy- P. PHI = 0. Not effective against aphids, may increase aphid problems when used for the control of other pests. Toxic to fish. Classified by EPA as a C carcinogen.
- pyrethrin/rotenone (Pyrellin EC)

- Efficacy- P. PHI = ½ day. Not effective and may increase aphid problems. Toxic to fish.

Biopesticides currently registered:
- neem oil (Trilogy)
  - Efficacy- NA. PHI = 0 days. Toxic to bees, fish, and aquatic invertebrates. Biopesticide.

Other insecticides currently registered:
- endosulfan (Endosulfan 3 EC, Thionex 3EC, Thionex 50W)
  - Efficacy- G. PHI= 11 days. This product may no longer be used after July 2012 because its tolerance has been revoked. One application allowed per year. Used when an outbreak occurs close to harvest. Toxic to bees and shrimp. Restricted use pesticide.
- flonicamid (Beleaf 50 SG)
  - Efficacy- G. PHI = 0 days. Product operates by paralyzing mouth parts causing the aphid to slowly starve. Because of this slow control time, aphids may reproduce following application. Better for early season control since aphids may be found within harvested celery, resulting in rejected loads at market. Not as harmful to beneficial insects as other products. May also be used for controlling tarnished plant bug. Organophosphate replacement. Classified by EPA as a D carcinogen.
- pymetrozine (Fulfill)
  - Efficacy- G. PHI = 7 days. Not useful close to harvest because it works slowly (paralyzing the aphid mouth parts and starving the aphid) and any aphids found in a load of celery will result in rejection. Classified by EPA as a B2 carcinogen.
- spirotetramat (Movento)
  - Efficacy- NA. PHI = 3 days. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Minimum of 7 days between applications; do not apply more than 10 fl. oz. per season. Toxic to aquatic invertebrates and potential risk to honeybee larvae. Reduced risk pesticide.

Other pest management aids:
- Use scouting to initiate management program. Start spraying when aphids are first detected.
- Sticky traps may be used to help monitor populations.

Pipeline pest management tools:
- Biologicals

"To do" list for aphids:
Research needs:
- Evaluate selective insecticides for use in resistance management for aphids. Need good comparative data among registered products.
- Evaluate the impact of biological control agents under selective insecticide aphid management programs.
- More insecticide options to combat insecticide resistance issues.

- Scouting in the greenhouse to set thresholds for initiation of control measures.
- Scheduling of insecticide applications and what to use with rotations.

Regulatory needs:
- Expansion in the greenhouse of products labeled for field use.

Education needs:
- Aphid biology and mode of action of insecticides.
- Create list of products that are coming up for re-registration and timing of their comment period.
- Scheduling of insecticide applications and efficacy of insecticide rotations.

2. **Aster leafhopper (*Macrosteles quadrilineatus*) –** Aster leafhoppers are one of the most important insect pests on celery because they vector aster yellows. Infection rate is used as a guide for setting the threshold and is a helpful tool for growers. Results of infectivity ratings are needed within four days of collecting samples but results of this test usually take longer than this. Infectivity ratings need to be local to attain accurate infectivity rates. Most leafhoppers migrate in the spring on wind currents from the south, however, small populations are known to overwinter. Wide host range, including many weeds which may act as reservoirs of disease inoculum.

Organophosphate insecticides currently registered:
- acephate (Acephate 97, Orthene 97)
  - Efficacy- G. PHI = 21 days. Aster leafhopper not listed under celery but is included within other crop types on label. Frequently used in rotation with methomyl. Only two applications per year allowed. Toxic to bees and birds. Classified by EPA as a C carcinogen.

Carbamate insecticides currently registered:
- carbaryl (Sevin 4 F, Sevin 80 WSP, Sevin XLR Plus)
  - Efficacy- G. PHI = 14 days. Not used very often to control aster leafhopper. Toxic to bees and aquatic invertebrates. Classified by EPA as a B2 carcinogen.
- methomyl (Lannate)
  - Efficacy- G. PHI = 7 days. Toxic to bees, mammals, aquatic invertebrates, and fish. High potential for contaminating ground water. Restricted use pesticide. Do not apply more than 24 pints/acre crop/season. Do not make more than 10 applications/season. Classified by EPA as an E chemical.

Neonicotinoid insecticides currently registered:
- clothianidin (Belay)
  - Efficacy- NA. PHI = 21 days. Lacking sufficient efficacy data in Michigan and also considered expensive, therefore chemical not widely used by growers. Toxic to bees and aquatic invertebrates and may easily contaminate ground water.
- dinotefuran (Scorpion 35SL, Venom, Venom 20 SG)
  - Efficacy- NA. PHI = 7 days (foliar treatments; Scorpion and Venom); 21 days (soil treatment; Venom). Lacking sufficient efficacy data in Michigan, therefore chemical

not used by growers. Also manages leaf miners. Toxic to bees and shrimp. High potential for contaminating ground water. Reduced risk pesticide. Organophosphate alternative.

- imidacloprid (Admire Pro, Nuprid 2F, Alias, many additional generic brands)
  - Efficacy- F. PHI = 45 days. Considered weak on Lepidoptera. Toxic to bees. High potential for contaminating ground water. Soil applied. Classified by EPA as an E chemical.
- thiamethoxam (Actara, Platinum, Platinum 75 SG)
  - Efficacy- NA. PHI = 7 days (foliar treatment; Actara), 30 days (soil treatment; Platinum). Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Also controls aphids. Toxic to bees, wildlife, and aquatic invertebrates. High potential for contaminating ground water.
- thiamethoxam/chlorantraniliprole (Voliam Flexi, Durivo)
  - Efficacy- NA. PHI = 7 days (foliar treatment; Voliam Flexi); 30 days (soil treatment; Durivo). Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Also controls cabbage loopers and aphids. Toxic to bees, aquatic invertebrates, shrimp, oyster, and wildlife. High potential for contaminating ground water.

Pyrethroid insecticides currently registered:

- beta-cyfluthrin (Baythroid XL)
  - Efficacy- G. PHI = 0 days. Aster leafhopper not listed under celery but is included within other crop types on label. Toxic to bees, fish, and aquatic invertebrates. Restricted use pesticide.
- permethrin (Ambush 25 W, Pounce 25 WP, Perm-UP 25DF, Perm-UP 3.2 EC)
  - Efficacy- G. PHI = 1 day. Used in rotation for resistance management, however, it can increase aphid populations. Toxic to bees, fish, and aquatic invertebrates. Restricted use pesticide. Classified by EPA as a B2 carcinogen.
- pyrethrin/piperonyl butoxide (Pyrenone)
  - Efficacy- NA. PHI = 0. Not effective against aphids, may increase aphid problems when used for the control of other pests. Toxic to fish. Classified by EPA as a C carcinogen.
- pyrethrin/rotenone (Pyrellin EC)
  - Efficacy- NA. PHI = ½ day. Not effective and may increase aphid problems. Toxic to fish.
- zeta-cypermethrin 2S (Mustang Max)
  - Efficacy- G. PHI = 1 day. Toxic to bees, fish, aquatic invertebrates, oyster, and shrimp. Restricted use pesticide. Minimum 7 days between applications. Classified by EPA as a C carcinogen.

Other insecticides currently registered:

- endosulfan (Endosulfan 3 EC, Thionex 3EC, Thionex 50W)
  - Efficacy- NA. PHI= 11 days. This product may no longer be used after July 2012 because its tolerance has been revoked. Lacking sufficient efficacy data in Michigan. Product is primarily used to control aphids. One application allowed per year. Used

when an outbreak occurs close to harvest. Toxic to bees and shrimp. Restricted use pesticide.

Other pest management aids:
- Weed control in and around fields.
- Planting near small grains or alfalfa should be avoided, because leafhopper activity in neighboring crops may increase dramatically during grain or alfalfa harvests.
- Infectivity index for assessing threshold.

Pipeline pest management tools:
- None.

"To do" list for aster leafhopper:
Research needs:
- Determine how long an application of Admire made to seedlings in the greenhouse will last after transplanting in the field.
- Evaluate the interaction of aster leafhopper with non-crop plants as a potential source of aster yellows infection and leafhopper alternate hosts.
- Real time, in field assessment method for determining aster yellows infectivity.
- Determine if and why geographic hot spots develop.

Regulations needs:
- None.

Education needs:
- Report pathogen infection rates in leafhoppers across regions in Michigan.
- Create list of products that are coming up for re-registration and timing of their comment period.

3. **Tarnished plant bug (*Lygus lineolaris*) –** This insect is found on numerous crops and can be a pest of celery that causes cosmetic damage important in fresh market. This insect can also reduce yields when young plants are attacked. Control measures are taken if insect numbers exceed 2-4 per 20 plants. Insect populations usually increase after hay cutting. Long lasting product needed with a short PHI.

Carbamate insecticides currently registered:
- carbaryl (Sevin 4 F, Sevin 80 WSP, Sevin XLR Plus)
  - Efficacy- G. PHI = 14 days. Not used very often to control tarnished plant bug. Toxic to bees and aquatic invertebrates. Classified by EPA as a B2 carcinogen.
- methomyl (Lannate)
  - Efficacy- G. PHI = 7 days. Tarnished plant bug not listed under celery but is included within other crop types on label. Toxic to bees, mammals, fish, and aquatic invertebrates. High potential for contaminating ground water. Restricted use pesticide. Classified by EPA as an E chemical.

Neonicotinoid insecticides currently registered:

- imidacloprid (Admire Pro, Nuprid 2F, Alias, many additional generic names)
  - Efficacy- G. PHI = 45 days. Tarnished plant bug not listed under celery but is included within other crop types on label. Used at planting only. Toxic to bees. High potential for contaminating ground water. Classified by EPA as an E chemical.

Pyrethroid insecticides currently registered:

- beta-cyfluthrin (Baythroid XL)
  - Efficacy- NA. PHI = 0 days. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Toxic to bees, fish, and aquatic invertebrates.
- permethrin (Pounce 25 WP)
  - Efficacy- G. PHI = 1 day. Tarnished plant bug not listed under celery but is included within other crop types on label. Used in rotation for resistance management, however, it can increase aphid populations. Toxic to bees, fish, and aquatic invertebrates. Restricted use pesticide. Classified by EPA as a B2 carcinogen.
- zeta-cypermethrin 2S (Mustang Max)
  - Efficacy- G. PHI = 1 day. Toxic to bees, fish, aquatic invertebrates, oyster, and shrimp. Restricted use pesticide. Minimum 7 days between applications. Classified by EPA as a C carcinogen.

Other insecticides currently registered:

- flonicamid (Beleaf 50 SG)
  - Efficacy- G. PHI = 0 days. Product is primarily used by growers for controlling aphids rather than tarnished plant bugs. Product operates by paralyzing mouth parts causing the aphid to slowly starve. Because of this slow control time, insects may reproduce following application. Better for early season control since insects may be found within harvested celery, resulting in rejected loads at market. Not as harmful to beneficial insects as other products. Classified by EPA as a D carcinogen.

Other pest management aids:

- Weed control around the field.
- Awareness of nearby activities, especially hay harvesting.
- Scouting: sweepnet.

Pipeline pest management tools:

- None.

"To do" list for tarnished plant bug:

Research needs:

- Development of usable economic thresholds.
- Better scouting techniques. Are there better times of day to scout, such as at night?

Regulatory needs:
- None.

Education needs:
- As new tools become available, educate growers on their use.
- Create list of products that are coming up for re-registration and timing of their comment period.

4. **Cutworms (Noctuidae) –** Can be an annual problem and has been a problem in recent years. Preventive treatments needed within 4 weeks of harvest.

Carbamate insecticides currently registered:
- carbaryl (10% Sevin Granules)
  - Efficacy- F. PHI = 14 days. Cutworms are not listed under celery but are included within other crop types on label. Toxic to bees and aquatic invertebrates. Classified by EPA as a B2 carcinogen.
- methomyl (Lannate LV, Lannate SP)
  - Efficacy- G. PHI = 7 days. Toxic to bees, aquatic invertebrates, fish, and mammals. High potential for contaminating ground water. Restricted use pesticide. Classified by EPA as an E chemical.

Pyrethroid insecticides currently registered:
- pyrethrin/piperonyl butoxide (Pyrenone)
  - Efficacy- NA. PHI = 0. Not effective against aphids, may increase aphid problems when used for the control of other pests. Toxic to fish. Classified by EPA as a C carcinogen.
- zeta-cypermethrin 2S (Mustang Max)
  - Efficacy- G. PHI = 1 day. Toxic to bees, fish, aquatic invertebrates, oyster, and shrimp. Restricted use pesticide. Minimum 7 days between applications. Classified by EPA as a C carcinogen.

Other insecticides currently registered:
- chlorantraniliprole (Coragen)
  - Efficacy - NA. PHI = 1 day. Is listed for use in celery but not listed for cutworms. Also controls loopers. Toxic to aquatic invertebrates, oyster, and shrimp. High potential for contaminating ground water. Reduced risk pesticide.
- flubendiamide (Synapse WG)
  - Efficacy- NA. PHI = 1 day. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Toxic to aquatic invertebrates.
- flubendiamide/buprofezin (Vetica)
  - Efficacy- NA. PHI = 7 days. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Toxic to aquatic invertebrates. Classified by EPA as a D carcinogen.
- methoxyfenozide (Intrepid 2F)

- Efficacy- NA. PHI = 1 day. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Potential toxicity to aquatic organisms. Reduced risk pesticide.

Pipeline pest management tools:
- None

"To do" list for Cutworms:
Research needs:
- Determine efficacy and develop use patterns of reduced risk insecticides and growth regulators.

Regulatory needs:
- None.

Education needs:
- Create list of products that are coming up for re-registration and timing of their comment period.

5. **Celery leaftier (*Udea rubigalis*)-** Considered a sporadic problem but was a noticeable pest in many celery fields within the 2010 growing season. The size of the leaf tier makes detecting infestations difficult until population sizes are large. It is often difficult for insecticides to reach the leaf tier in canopy. Not many insecticides are currently labeled for leaftier in celery, however it is likely that control methods for loopers may be effective against leaftier because of their biological similarities.

Pyrethroid insecticides currently registered:
- beta-cyfluthrin (Baythroid XL)
  - Efficacy- NA. PHI = 0 days. Leaftier is included on label but is not included within the celery section of the label. Toxic to bees, fish, and aquatic invertebrates.
- pyrethrin/piperonyl butoxide (Pyrenone)
  - Efficacy- NA. PHI = 0 days. Leaftier is included on label but is not included within the celery section of the label. May increase aphid problems. Toxic to fish. Classified by EPA as a C carcinogen.
- pyrethrin/rotenone (Pyrellin EC)
  - Efficacy- NA. PHI = ½ days. May increase aphid problems. Toxic to fish.
- zeta-cypermethrin 2S (Mustang Max)
  - Efficacy- NA. PHI = 1 day. Leaftier is included on label but is not included within the celery section of the label. Toxic to bees, fish, aquatic invertebrates, oyster, and shrimp. Restricted use pesticide. Minimum 7 days between applications. Classified by EPA as a C carcinogen.

Biopesticides currently registered:
- *Bacillus thuringiensis* (Agree WG, Biobit HP, Dipel, Javelin WG, Xentari DF)
  - Efficacy- NA. PHI = 0 days. Leaftier is not listed on label, but product is likely to control this pest. Lacking sufficient efficacy data in Michigan, therefore chemical not

widely used by growers. Efficacy depends on timing of application. Can be slow to control loopers and damage can occur before it starts to be effective. Chemical has too narrow of a target group and is rarely used to control loopers when other insect pests are present. Residual activity sometimes low. Toxic to nontarget lepidoptera, green lacewing, and *Metaseiulus occidentalis* (predatory mite). Biopesticide.

Other insecticides currently registered:

- chlorantraniliprole (Coragen)
  - Efficacy- NA. PHI = 1 day. Leaftier is not listed on label, but product is likely to control this pest. Toxic to aquatic invertebrates, oyster, and shrimp. High potential for contaminating ground water. Reduced risk pesticide.
- flubendiamide/buprofezin (Vetica)
  - Efficacy- NA. PHI = 7 days. Leaftier is included on label but is not included within the celery section of the label. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Toxic to aquatic invertebrates. Classified by EPA as a D carcinogen.

Other pest management aids:

- Scouting

Pipeline pest management tools:

- None.

"To do" list for Leaftier:

Research needs:

- Direct comparative studies with products that are lacking efficacy data.

Regulatory needs:

- None

Education needs:

- Create list of products that are coming up for re-registration and timing of their comment period.

6. **Loopers (celery looper [*Anagrapha falcifera*], cabbage looper [*Trichoplusia ni*],–** Controlled as needed. Main problem occurs with cocoons found in harvested celery, resulting in rejection of load.

Organophosphate insecticides currently registered:

- acephate (Acephate 97 UP, Orthene 97)
  - Efficacy- G. PHI = 21 days. PHI considered too long for many growers. Toxic to birds and bees. Classified by EPA as a C carcinogen.

Carbamate insecticides currently registered:

- methomyl (Lannate LV, Lannate SP)

- Efficacy- G. PHI = 7 days. Commonly used. Toxic to birds, bees, fish, and mammals. High potential for contaminating ground water. Restricted use pesticide. Classified by EPA as an E chemical.

Neonicotionoid insecticides currently registered:

- thiamethoxam / chlorantraniliprole (Voliam Flexi, Durivo)
  - Efficacy- NA. PHI = 7 days (Voliam Flexi) and 30 days (Durivo). Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Also controls aphids. Toxic to bees, wildlife, and aquatic invertebrates. High potential for contaminating ground water.

Pyrethroid insecticides currently registered:

- beta-cyfluthrin (Baythroid XL)
  - Efficacy- G. PHI = 0 days. Toxic to bees, fish, and aquatic invertebrates.
- permethrin (Ambush 25 W, Pounce 25 WP, Perm-UP 25DF, Perm-UP 3.2 EC)
  - Efficacy- G. PHI = 1 day. Used in rotation for resistance management, however, it can increase aphid populations. Toxic to bees, fish, and aquatic invertebrates. Restricted use pesticide. Classified by EPA as a B2 carcinogen.
- pyrethrin/piperonyl butoxide (Pyrenone)
  - Efficacy- G. PHI = 0 days. May increase aphid problems. Toxic to fish. Classified by EPA as a C carcinogen.
- pyrethrin/rotenone (Pyrellin EC)
  - Efficacy- G. PHI = ½ days. May increase aphid problems. Toxic to fish.
- zeta-cypermethrin 2S (Mustang Max)
  - Efficacy- G. PHI = 1 day. Toxic to bees, fish, aquatic invertebrates, oyster, and shrimp. Restricted use pesticide. Minimum 7 days between applications. Classified by EPA as a C carcinogen.

Biopesticides currently registered:

- *Bacillus thuringiensis* (Agree WG, Biobit HP, Dipel, Javelin WG, Xentari DF)
  - Efficacy- NA. PHI = 0 days. Lacking sufficient efficacy data in Michigan, therefore chemical not widely used by growers. Efficacy depends on timing of application. Can be slow to control loopers and damage can occur before it starts to be effective. Chemical has too narrow of a target group and is rarely used to control loopers when other insect pests are present. Residual activity sometimes low. Toxic to nontarget lepidoptera, green lacewing, and *Metaseiulus occidentalis* (predatory mite). Biopesticide.

Other insecticides currently registered:

- chlorantraniliprole (Coragen)
  - Efficacy- F. PHI = 1 day. Toxic to aquatic invertebrates, oyster, and shrimp. High potential for contaminating ground water. Reduced risk pesticide.
- emamectin benzoate (Proclaim)
  - Efficacy- G. PHI = 7 days. Not widely used. Apply when larvae are first observed. Ground or aerial application is permitted.
- endosulfan (Endosulfan 3 EC, Thionex 3EC, Thionex 50W)

- Efficacy- G. PHI= 11 days. This product may no longer be used after July 2012 because its tolerance has been revoked. One application allowed per year. Used when an outbreak occurs close to harvest. Toxic to bees and shrimp. Restricted use pesticide.

- flubendiamide/buprofezin (Vetica)
  - Efficacy- NA. PHI = 7 days. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Toxic to aquatic invertebrates. Classified by EPA as a D carcinogen.
- indoxacarb (Avaunt)
  - Efficacy- NA. PHI = 3 days. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Toxic to bees, birds, mammals, fish, and aquatic invertebrates.
- methoxyfenozide (Intrepid 2F)
  - Efficacy- NA. PHI = 1 day. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Potential toxicity to aquatic organisms. Reduced risk pesticide.
- spinetoram (Radiant SC)
  - Efficacy- NA. PHI = 1 day. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Toxic to bees and aquatic invertebrates. Reduced risk pesticide.
- spinosad (Entrust)
  - Efficacy- NA. PHI = 1 day. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Do not apply more than 3 times in 21 days. Toxic to bees and aquatic invertebrates. Reduced risk pesticide.
- tebufenozide (Confirm)
  - Efficacy- NA. PHI = 7 day. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Do not apply more than 8 fl oz per application and do not exceed 56 fl oz product per season. Classified by EPA as an E chemical.

Other pest management aids:

- Scouting

Pipeline pest management tools:

- None.

"To do" list for Loopers:

Research needs:

- Direct comparative studies with products currently not widely used.

Regulatory needs:

- None.

Education needs:

- Create list of products that are coming up for re-registration and timing of their comment period.

7. **Carrot weevil (*Listronotus oregonensis*)** – Minor pest, usually controlled by insecticides targeting other pests. When it is a problem, it is usually in non-rotated fields, early in the season. Locality differences in severity are usually observed. Carrots and related weeds can act as alternate hosts to the insect. Insect overwinters as adults in ditches.

   Carbamate insecticides currently registered:
   - oxamyl (Vydate L)
     - Efficacy- VG. PHI = 21 days. Start application when eggs or larvae are first seen and repeat 2-3 weeks later. Product is expensive but translocates into the roots and affects the larvae. Also used for control of nematodes. Toxic to bees, aquatic invertebrates, birds, fish, and mammals. High potential for contaminating ground water. Restricted use pesticide. Classified by EPA as an E chemical.

   Pyrethroid insecticides currently registered:
   - pyrethrin/piperonyl butoxide (Pyrenone)
     - Efficacy- NA. PHI = 0. Not effective against aphids, may increase aphid problems when used for the control of other pests. Toxic to fish. Classified by EPA as a C carcinogen.

   Other pest management aids:
   - Crop rotation.
   - Scouting: trapping.

   Pipeline pest management tools:
   - None.

   "To do" list for carrot weevil larvae:
   Research needs:
   - None.

   Regulatory needs:
   - Labeling for insecticides registered for use in the field for use in the greenhouse.

   Education needs:
   - None.

8. **Vegetable leaf miner (Agromyzidae) –** This insect is a sporadic pest, appearing only when environmental conditions are favorable. Often resides in weeds. Resistance to insecticides is a problem.

   Organophosphate insecticides currently registered:
   - dimethoate (Dimethoate 2.67 EC, Dimethoate 4 EC, Dimethoate 4E)
     - Efficacy – NA. PHI = 7. Labeled for leaf miner but is also effective at controlling aphids. Toxic to wildlife, aquatic invertebrates, and bees. May easily contaminate ground water. Classified by EPA as a C carcinogen.

Neonicotinoid insecticides currently registered:

- dinotefuran (Scorpion 35SL, Venom, Venom 20 SG)
  - Efficacy- NA. PHI = 7 days (foliar treatment) and 21 days (soil treatment). Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Also manages leafhoppers. Toxic to bees and shrimp. High potential for contaminating ground water. Reduced risk pesticide. Organophosphate alternative.
- thiamethoxam / chlorantraniliprole (Voliam Flexi, Durivo)
  - Efficacy- NA. PHI = 7 days (Voliam Flexi) and 30 days (Durivo). Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Also controls aphids. Toxic to bees, wildlife, and aquatic invertebrates. High potential for contaminating ground water.

Pyrethroid insecticides currently registered:

- permethrin (Ambush 25 W, Perm-UP 25DF, Perm-UP 3.2 EC, Pounce 25 WP)
  - Efficacy- NA. PHI = 1 day. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Toxic to bees, fish, and aquatic invertebrates. Restricted use pesticide. Classified by EPA as a B2 carcinogen.
- pyrethrin/piperonyl butoxide (Pyrenone)
  - Efficacy- NA. PHI = 0. Not effective against aphids, may increase aphid problems when used for the control of other pests. Toxic to fish. Classified by EPA as a C carcinogen.
- pyrethrin/rotenone (Pyrellin EC)
  - Efficacy- NA. PHI = ½ day. Not effective and may increase aphid problems. Toxic to fish.

Other insecticides currently registered:

- abamectin (Agri-Mek 0.15 EC)
  - Efficacy- G. PHI = 7 days. Toxic to bees, fish, and mammals. Potentially toxic to amphibians, crustaceans and non-target insects.
- chlorantraniliprole (Coragen)
  - Efficacy- NA. PHI = 1 day. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Can be used as a foliar or soil treatment. Toxic to aquatic invertebrates, oysters, and shrimp. High potential for contaminating ground water. Reduced risk pesticide.
- cyromazine (Trigard)
  - Efficacy- G. PHI = 7 days. Most commonly used although it is expensive. It is slow acting and multiple applications are necessary. High potential for contaminating ground water. Classified by EPA as an E chemical.
- spinetoram (Radiant SC)
  - Efficacy- NA. PHI = 1 day. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Toxic to bees and aquatic invertebrates. Reduced risk pesticide.
- spinosad (Entrust)
  - Efficacy- NA. PHI = 1 day. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Toxic to bees and aquatic invertebrates. Reduced risk pesticide.

Other pest management aids:
- Scouting.

Pipeline pest management tools:
- None.

"To do" list for vegetable leaf miner:
Research needs:
- Effects of crop rotation on insect incidence.
- Efficacy trials using spinosad.

Regulatory needs:
- None.

Education needs:
- None.

9. **Wireworms (Elateridae) –** Minor problem depending on field location. They are most damaging to young plants. No control measures are used.

Pyrethroid insecticides currently registered:
- zeta-cypermethrin 2S (Mustang Max)
  - Efficacy- NA. PHI = 1 day. Toxic to bees, fish, aquatic invertebrates, oyster, and shrimp. Restricted use pesticide. Minimum 7 days between applications. Classified by EPA as a C carcinogen.

"To do" list for wireworms:
Research needs:
- Monitoring populations for potential problems in the future.

Regulatory needs:
- None.

Education needs:
- None.

NEMATODES

The following are listed in order of importance to the celery industry of Michigan.

1. **Northern root-knot nematode (*Meloidogyne hapla*)** – Most important nematode problem in Michigan celery production. Distribution spotty, both between farms and fields and within fields. Limited host range compared with other nematode problems with celery. Symptoms consist of stunted plants, uneven growth, yellowing, and small but numerous root galls.

2. **Pin nematode (*Paratylenchus hamatus*)** – Serious problem in a small number of locations. Symptoms include severely stunted plants of uneven growth and no lateral root growth (witches broom symptoms).

3. **Needle nematode (*Longidorus elongatus*) –** Problem rare, but known to exist in Michigan celery production. Symptoms consist of stunted plants with swollen root tips.

4. **Root-lesion nematode (*Pratylenchus penetrans*)** – Very wide host range and the most common plant parasitic nematode in Michigan. Can result in celery yield losses; however, relatively little is known about this in Michigan celery production. Causes root stunting and discoloration.

Carbamate nematicides currently registered:

- oxamyl (Vydate)
  - Efficacy- F-G. Most effective when used in multiple applications at a low rate. Also used to control carrot weevil larvae and aphids. May not be effective in some locations in Michigan. Interest among celery growers in applying oxamyl through trickle irrigation. Toxic to bees, birds, fish, and aquatic invertebrates. High potential for contaminating ground water. Restricted use pesticide. Classified by EPA as an E chemical.

Other nematicides currently registered:

- 1, 3-Dichloropropene (Telone II) (fumigant)
  - Efficacy- NA. Not used because of the cost of the product, the specialized application equipment required, and the lack of efficacy data in Michigan. Soil temperature requirements needed for application also limit its use in celery production in Michigan. High potential for contaminating ground water. Restricted use pesticide. Classified by EPA as a B2 carcinogen.
- metam (various commercial products marketed)
  - Efficacy- NA. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Most commonly used soil fumigant in Michigan agriculture. Applied either as a soil injected fumigant or through irrigation systems. Toxic to fish. Classified by EPA as a B2 carcinogen.

Other pest management aids:

- Green manure crops (i.e. oil seed, radish, sudan grass, mustards) need to be plowed down, avoid legumes (clovers, alfalfa and vetch) unless established for two or more years.
- Crop rotation. However, using legumes within crop rotation may increase root-knot nematode populations.

Pipeline pest management tools:

- New nematicides.
- Seed treatments
  - Evicta
  - Botiva (biological)

- Pasteuria bacterial
- *Bacillus firmus*
- Non host trap crops
  - oil seed radish
- Biofumigation
- Soil quality

"To do" list for nematodes:
Research needs:
- Investigate cover crop options.
- Investigate role of soil quality (particularly muck) in relation to nematode problems.
- Other application methods for nematicides.

Regulatory needs:
- Retention of oxamyl.

Education needs:
- Educate growers, field and extension personnel to recognize symptoms on plants.
- Teach field personnel how to sample fields for nematodes.

OTHER INVERTEBRATE PESTS

1. **Spider mites-** An occasional problem during hot, dry conditions especially around the edges of fields. Symptoms include stunted growth, yellowing. Unsightly webbing can result in rejected celery loads. Typically occur on fringes of fields and are usually found in the same locations from year to year.

Organophosphate miticides currently registered:
- dimethoate (Dimethoate 2.67 EC, Dimethoate 4 EC, Dimethoate 4E)
  - Efficacy – F. PHI = 7. Toxic to wildlife, aquatic invertebrates, and bees. May easily contaminate ground water. Classified by EPA as a C carcinogen.
- malathion (Malathion 5, Malathion 5 EC, Malathion 57 EC, Malathion 8)
  - Efficacy- NA. PHI = 7 days. Lacking sufficient efficacy data in Michigan, therefore chemical not used by growers. Toxic to bees, birds, fish, amphibians, and other aquatic organisms. Classified by EPA as a D carcinogen.

Biopesticides currently registered:
- neem oil (Trilogy)
  - Efficacy- NA. PHI = 0 days. Toxic to bees, fish, and aquatic invertebrates. Biopesticide.

Other Miticides currently registered:
- abamectin (Agri-Mek 0.15EC)
  - Efficacy- VG. PHI = 7 days. Potential for pest to develop resistance. Toxic to bees, mammals, and fish. Potential toxicity to amphibians, crustaceans, and non-target insects.

Other pest management aids:
- Naturally occurring predatory mites are not considered effective in the field.

Pipeline pest management tools:
- Oberon

"To do" list for spider mites:
Research needs:
- Identify and test alternative products.

Regulatory needs:
- Expedite registration of newer products.
- Register Oberon for celery (Partner with IR-4).

Education needs:
- Scouting.

2. **Slugs –** An uncommon pest, when a problem occurs it is generally in the greenhouse.

Pesticides currently registered:
- metaldehyde (Deadline M-Ps 4%, Metaldehyde 3.5G)
  - Efficacy- NA. This product is still available to use. However, maximum residue limits have not been set and celery will soon not be listed on this product in the future. At this time EPA has not determined when the label will switch. Classified by EPA as a C carcinogen.

Other pest management aids:
- Scouting

Research needs:
- None.

Regulatory needs:
- Partner with IR-4 to check tolerances for metaldehyde.

Education needs:
- None.

PATHOGENS

<u>Bacterial pathogens</u>

1. **Bacterial Blight (*Pseudomonas syringae* pv. *apii*)** – Initially causes small, reddish, angular spots that have a slightly greasy appearance and occur on both sides of leaves [4, 5]. With time, lesions grow and develop a darker brown coloration [5]. This disease can be a major problem in the field and greenhouse, but it does not typically kill the plants. The bacteria enter the tissue through stomates and hydathodes and symptoms appear several days after

inoculation [4]. Can also be seed borne in which it can survive 2-3 years on seeds [5]. Warm, wet weather present ideal conditions for this disease. Preventive chemical applications are used starting at beginning of growing season and is used in the greenhouse by some growers. Infection is most prevalent during the fall.

Pesticides currently registered:

- copper ammonium carbonate (Copper Count N)
  - Efficacy- F. Not typically used. Toxic to fish and aquatic organisms.
- copper hydroxide (Kocide 2000, Kocide 3000, Champ Formula 2 F, Champ DP, Champion WP, Nu-Cop 3L, Nu-Cop 50DF)
  - Efficacy- F, must be applied prior to disease incidence, better for use in greenhouse when bacterial populations are lower and environmental conditions are favorable. Most commonly used copper formulation. Toxic to fish and aquatic organisms.
- copper oxychloride / copper sulfate (C-O-C-S WDG)
  - Efficacy- F. Not typically used. Toxic to fish and aquatic organisms.
- copper sulfate (Cuprofix Ultra)
  - Efficacy- F. PHI = 0 days. Toxic to fish and aquatic organisms.

Other pest management aids:

- Plant treated seed. Seed treated with hot water is common, however this treatment generally reduces germination.
- Crop rotation may be helpful, but the disease can be seed-borne. Rotations that have been used include: 4 years of celery and 1 year of corn; 1 year of celery and 1 year of onion or radish; two years of celery and then leave the field fallow.
- Greenhouse cultural management to reduce bacterial populations including sanitation.
- Post-harvest tilling to speed breakdown of infected plant debris to reduce pathogen survival in the field.
- Monitor areas of field that favor disease development which include woodlots, low areas, and fence rows.
- Keep greenhouse and planting equipment clean. Disinfest transplant trays prior to use.

Pipeline pest management tools:

- Actigard.
- Plant inducer materials.
- Anti-bacterial reducing products.

"To do" list for bacterial blight:

Research needs:

- Test pipeline pest management tools for efficacy against bacteria and plant phytotoxicity.
- Tracking bacterial populations in the greenhouse, using PCR fingerprinting as a tool.
- Alternative seed treatments.
- Variety resistance screening. Peto 285 and Duchess seem to be very susceptible.
- Determine the ability of the bacterium to survive in the greenhouse between crops.
- Better way to disinfest seed in lieu of hot water treatment.

Regulatory needs:

- Monitor labels for changes in label for REI and PPE.
- Expand the list of greenhouse products to list damping off and bacterial blight.
- Does copper use in greenhouse count against use in field for yearly limit?

Education needs:

- Emphasize sanitation techniques for the greenhouse. Understand the potential source of inoculum and the importance of implementing management strategies in the greenhouse.

2. **Soft Rot (*Erwinia carotovora*) –** Affected areas appear water-soaked, develop a soft decay, and have a distinctive foul odor. This bacterium, generally thought to be a secondary pathogen, usually infects plants through wounds or other injured areas. May be observed more during hot and humid summers in low areas of fields, and during post-harvest. Because of its sporadic nature, and because stalks that are affected are generally unmarketable anyway, there are no treatments recommended except for prevention through the usual sanitation practices.

<u>Fungal pathogens</u>

3. **Crater Rot (*Rhizoctonia solani*)** – Causes small (3-8 mm) brown to large (5 cm), sunken, brick-red lesions on the inner and outer petioles (stalks) of the plant [5]. The basidiomycete fungus that causes infection inhabits soil organic matter. Periodic problem and is usually controlled using current products. Usually appears during hot weather.

Pesticides currently registered:

- azoxystrobin (Amistar, Quadris)
  - Efficacy- G. PHI = 0 days. Toxic to fish and aquatic invertebrates. Reduced risk pesticide.
- azoxystrobin/chlorothalonil (Quadris Opti)
  - Efficacy- G. PHI = 7 days. Toxic to fish, aquatic invertebrates, and wildlife. High potential for contaminating ground water. Classified by EPA as a B2 carcinogen.
- chlorothalonil (Bravo Ultrex, Equus DF, Bravo Weather Stik, Equus 720SST, Echo 90DF, Echo 720, Echo Zn)
  - Efficacy- F. PHI = 7 days. Most commonly used for crater rot and other fungal pathogens. Reasonably priced, very cost effective. Toxic to aquatic invertebrates and wildlife. High potential for contaminating ground water. Classified by EPA as a B2 carcinogen.
- DCNA (Botran)
  - Efficacy - F. PHI = 7. Crater rot not listed on label. Expensive and not widely available to Michigan growers. Toxic to fish.
- potassium phosphite/chlorothalonil (Catamaran)
  - Efficacy- P. PHI = 7 days. Both active ingredients are listed for greenhouse use. Toxic to aquatic invertebrates and wildlife. Classified by EPA as a B2 carcinogen.

Other pest management aids:

- Keep soil off of crown when cultivating.

- Planting on raised beds.

Pipeline pest management tools:
- Luna products
- Inspire

"To do" list for crater rot:
Research needs:
- Determine the optimum planting depth to reduce disease. Does planting too deep increase problem?
- Determine the efficacy of unregistered products to control *Rhizoctonia*.
- Devise rotational strategies to reduce pathogen inoculum.

Regulatory needs:
- Determine the registration timeline for chlorothalonil.
- Maintain all currently registered products.

Education needs:
- None.

4. **Damping off (*Pythium* sp., *Rhizoctonia solani*) –** A common soil inhabitant that causes stunted growth, chlorotic foliage, and reddish-brown lesions on the roots [5]. The Pythium induced disease is favored by wet soil conditions, which allows the zoospores to come into contact with root tissue and cause infection [5]. Damping off is a sporadic problem that can cause serious losses in the seedbeds of greenhouses and in the field.

Pesticides currently registered:
- mefenoxam (Ridomil Gold GR, Ridomil Gold SL, Ultra Flourish) – seed or, in-furrow treatment
  - Efficacy- G on *Pythium* in the field, however it is expensive and is not registered for use in greenhouse, due to resistance issues. High potential for contaminating ground water. Classified by EPA as a B2 carcinogen.

Other pest management aids:
- Crop rotation to reduce pathogen inoculum.
- Good soil drainage.
- Focus on disease management in the greenhouse.
- Watering, sanitation, disinfest planting trays.

Pipeline pest management tools:
- Valent new product V-10208.

"To do" list for damping off:
Research needs:
- *Pythium* control strategies, especially in the greenhouse.
- Strobilurbin efficacy on *Rhizoctonia*.

- Test new products for control.

Regulatory needs:
- Label expansion to include products for use in the greenhouse.
- Ensure that new products do not prohibit use in the greenhouse.
- Expand products that are registered for *Pythium*. Many companies do not register products for *Pythium*.

Education needs:
- None.

5. **Foliar Leaf Blights; Early Blight (*Cercospora appii*) and Late Blight (*Septoria apiicola*) –** Both blights cause major problems and occur every season. Yield losses occur as a result of defoliation and stunting of the plants and petiole blighting. Varietal resistance and disease-free seed are important. Both pathogens can be seed borne. Symptoms of *Cercospora* early blight include yellow to tan spots, circular-shaped lesions on the upper and lower surface of leaves and elongate lesions on petioles. *Septoria* late blight is the most common disease of celery in Michigan, and spreads quickly. Symptoms of *Septoria* late blight include yellow to brown, irregularly shaped lesions on the leaves and petioles. Embedded in these lesions are small, black pycnidia, which are the reproductive structures of the fungus.

   Biopesticides currently registered:
   - neem oil (Trilogy)
     - Efficacy- P. PHI = 0 days. Toxic to bees, fish, and aquatic invertebrates. Biopesticide.

   Pesticides currently registered:
   - azoxystrobin (Amistar, Quadris)
     - Efficacy- G. PHI = 0 days. Expensive and must be used in rotation with fungicides of a different mode of action for resistant management. Reduced-risk product, however, growers question its efficacy and effects on yield (potential to act as a growth regulator especially when used in combination with other fungicides). Toxic to fish and aquatic invertebrates.
   - azoxystrobin / chlorothalonil (Quadris Opti)
     - Efficacy- E. PHI = 7 days. Toxic to fish, aquatic invertebrates, and wildlife. High potential for contaminating ground water. Classified by EPA as a B2 carcinogen.
   - azoxystrobin / propiconazole (Quilt, Quilt Xcel)
     - Efficacy- G. PHI = 14 days. Toxic to fish and aquatic invertebrates. High potential for contaminating ground water. Classified by EPA as a C carcinogen.
   - chlorothalonil (Bravo Ultrex, Equus DF, Bravo Weather Stik, Equus 720SST, Echo 90DF, Echo 720, Echo Zn)
     - Efficacy- E. PHI = 7 days. Most important tool against blights. Cost effective. Toxic to aquatic invertebrates and wildlife. Classified by EPA as a B2 carcinogen.
   - copper ammonium carbonate (Copper Count N)
     - Efficacy- P. Not used as a stand-alone product. Inexpensive. Toxic to fish and aquatic organisms.

- copper hydroxide (Kocide 2000, Kocide 3000, Champ Formula 2F, Champ DP, Champion WP, Nu-Cop 3L, Nu-Cop 50DF)
  - Efficacy- F. Not used as a stand-alone product. Inexpensive. Toxic to fish and aquatic organisms.

- copper oxychloride / copper sulfate (C-O-C-S WDG)
  - Efficacy- P. Not used as a stand-alone product. Inexpensive. Toxic to fish and aquatic organisms.
- copper sulfate (Basic Copper 53, Basicop, Cuprofix Ultra)
  - Efficacy- P. Not used as a stand-alone product. Inexpensive. Toxic to fish and aquatic organisms.
- fenamidone (Reason 500SC)
  - Efficacy- P. PHI = 2 days. Toxic to fish, aquatic invertebrates, oysters, and shrimp.
- potassium phosphite/chlorothalonil (Catamaran)
  - Efficacy- F. PHI = 7 days. Toxic to aquatic invertebrates and wildlife. Classified by EPA as a B2 carcinogen.
- propiconazole (Propimax EC, Tilt)
  - Efficacy- F. PHI = 14 days. Commonly used in rotation with Bravo. May have growth regulator affects. Toxic to fish. Classified by EPA as a C carcinogen.
- pyraclostrobin (Cabrio)
  - Efficacy- G. PHI = 0 days. Toxic to fish and aquatic invertebrates.
- trifloxystrobin (Flint, Gem 500)
  - Efficacy- G. PHI = 7 days. Toxic to fish and aquatic invertebrates. High potential for contaminating ground water. Reduced risk pesticide.

Other pest management aids:
- Plant certified, tested and treated seed.
- Post-harvest tilling to speed breakdown of infected plant debris in the field.
- Scouting to ensure early disease detection.

Pipeline pest management tools:
- Fontelis
- Inspire
- Luna

"To do" list for foliar blights:
Research needs:
- Overwintering of inoculum.
- Develop disease tolerant cultivars suitable for Michigan and targeted markets.
- Tom-Cast with newer products (Quilt, Quadris Opti).
- Coppers and biocontrol agents.
- Determine timing of initial applications for foliar disease control.

Regulatory needs:
- Continued registration of Bravo.
- Expedited registration of pipeline products.

- Keep single active ingredient products available.
- Clarify minimal interval of each active ingredient.

Education needs:
- Updating on new products, such as Quadris Opti and Quilt, and how they can be used in spray programs.

6. **Anthracnose (*Colletotrichum acutatum*) –** Found in celery fields in 2010 but has not been reported in Michigan previously. Causes leaves to cup and brown slender lesions along the petioles. Cracking has been found in some infections, however it is unknown if this symptom is actually caused by the disease. Little is known about how this disease in Michigan.

Pesticides currently registered:
- azoxystrobin (Amistar, Quadris)
  - Efficacy- NA. PHI = 0 days. On the label *Colletotrichum acutatum* is not listed within celery, however *Colletotrichum spp.* is listed within other crops. Toxic to fish and aquatic invertebrates. Reduced risk pesticide.
- chlorothalonil (Bravo Ultrex, Equus DF, Bravo Weather Stik, Equus 720SST, Echo 90DF, Echo 720, Echo Zn)
  - Efficacy- NA. PHI = 7 days. On the label *Colletotrichum acutatum* is not listed within celery, however *Colletotrichum spp.* is listed within other crops. Most commonly used for crater rot and other fungal pathogens. Reasonably priced, very cost effective. Toxic to aquatic invertebrates and wildlife. High potential for contaminating ground water. Classified by EPA as a B2 carcinogen.
- pyraclostrobin (Cabrio)
  - Efficacy- NA. PHI = 0 days. Toxic to fish and aquatic invertebrates.

Other pest management aids:
- None

Pipeline pest management tools:
- None.

"To do" list for anthracnose:
Research needs:
- Fungicide efficacy.
- Cultivar screening.
- Epidemiology and survival potential in Michigan. What weather conditions are required by anthracnose for infection?
- Stage of growth of celery that is most susceptible.
- Growing practices that could limit infection; crop rotation, plant spacing, spray patterns and coverage (optimizing spraying).

Regulatory needs:
- Make sure new products include celery on label for control of anthracnose.

Education needs:
- Calibration of sprayers, best spray coverage.
- Most effective products.
- Environmental conditions that favor disease development.

7. **Fusarium Yellows (*Fusarium oxysporum* f. sp. *apii*) –** A major problem with no known effective chemical control. The introduction of the resistant cultivar, Tall Utah 52-70 in the 1950s, halted *Fusarium* disease problems until recently where significant yield and quality losses have been sighted in California and Florida on previously resistant cultivars. The fungus causes yellowing and stunting, and vascular discoloration inside the crown and petiole. Disease is wide spread with incidence and severity varying by locality and stress level of plants. This problem is still increasing in Michigan and there may be a difference in races from other states. Recently developed cultivars are losing tolerance to this disease in Michigan.

   Pesticides currently registered:
   - None.

   Other pest management aids:
   - Planting resistant cultivars.
   - Crop rotation (minimum 2-3 years with onion or lettuce) may help, but not as a stand alone tool.
   - Water and nutrient management to reduce plant stress may help increase plant resistance, but is not a stand alone tool.

   Pipeline pest management tools:
   - Biological controls have been studied in the past but were not effective.
   - Develop new resistant cultivars.

   "To do" list for Fusarium yellows:
   Research needs:
   - Development of disease resistant varieties and identification of alternative resistance pathways.
   - Determine range of virulence and number of races.
   - Maintain current collection of cultivars and germplasm. Save germplasm material from merging companies and add to the USDA germplasm collection.

   Regulatory needs:
   - None.

   Education needs:
   - Need for variety development.

8. **White or Pink Mold (*Sclerotinia sclerotiorum*) –** A soil pathogen that causes soft brown lesions with a pinkish border that can collapse the plants. Brown foliar blighting may also

occur. Generally of minor economic significance. Occasionally causes damage in the field and in storage. Because of the use of chlorothalonil (Bravo) to control other diseases, white or pink mold is rarely a problem.

Pesticides currently registered:

- chlorothalonil (Bravo Ultrex, Equus DF, Bravo Weather Stik, Equus 720SST, Echo 90DF, Equus DF)
  - Efficacy- G. PHI = 7 days. Very important and widely used. A broad-spectrum fungicide used mainly on foliar blights. Toxic to aquatic invertebrates and wildlife. Classified by EPA as a B2 carcinogen.
- cyprodinil/fludioxonil (Switch 62.5WG)
  - Efficacy- NA. PHI = 0 days. Toxic to fish and aquatic organisms. High potential for contaminating ground water.
- DCNA (Botran 75W)
  - Efficacy- NA. PHI = 7 days. Specific to white mold. Toxic to fish.

Other pest management aids:

- None.

Pipeline pest management tools:

- None.

"To do" list for white mold:
Research needs:

- Test currently unregistered and newly registered products for efficacy.

Regulatory needs:

- None.

Education needs:

- None.

<u>MLO, Viral pathogens, and physiological diseases</u>

9. **Aster Yellows –** See Aster Leafhopper

10. **Heart Mosaic (Cucumber mosaic virus) –** See aphids. Causes a mottling of celery leaflets and sunken, buff-colored streaks and spots on petioles. Wide host range and can overwinter in many cultivated and wild plants.

11. **Black streak -** A physiological disorder that causes black streaks along the petiole of the plant. Streaks are only visible once the petiole has been cut open. Generally occurs with high temperatures in the field. The Duchess variety seems to be more susceptible to this disorder whereas the Greenbay variety displays more resistance.

WEEDS

Annual and perennial grasses and broadleaf weeds. It is a common practice to rotate herbicides that have different modes of action in order to guard against resistance, but Michigan celery growers are limited in their ability to do so, because compared to other agricultural crops, there are fewer herbicides registered for use on celery.

Most Problematic Weeds

- Common groundsel
- Marsh yellowcress
- Smartweed/ladysthumb
- Yellow nutsedge
- Common purslane
  - Has shown resistance to the chemicals Lorox and Caparol. However, the level of resistance to these products is uncertain.
- Queen Anne's lace (wild carrot)
- Velvet leaf
- Giant ragweed
- Pineapple weed
  - Not a major problem.
- Galinsoga
  - More recent weed, however not a major problem.

1. **Pre-plant** (Herbicides used in preparation or prior to planting)**:**
   - glyphosate (Roundup 4L)
     - Efficacy- VG. Good for clearing fields of cover crops prior to planting. Occasionally used for ditch banks, cover crops, quack grass, and controlling weeds before transplants in later summer months. Cannot be used during production or with a wiper (wick) applicator. No residual activity. Reduced risk pesticide. Classified by EPA as an E chemical.

2. **Pre-emergence herbicides** (Used prior to weed emergence and prior to or following celery transplanting)**:**
   - flumioxazin (Chateau 51WDG)
     - Efficacy- VG. Good at controlling annuals and composites. Toxic to aquatic invertebrates and non-target plants.
   - metolachlor (Dual Magnum 7.6E)
     - Efficacy- G. Special label (24c third party) needed because of concerns about breakdown products and is undergoing EPA cumulative assessment. Mainly used to control nutsedge and pigweed. High potential for contaminating ground water. Classified by EPA as a C carcinogen.
   - trifluralin (Treflan)
     - Efficacy: G. Generally not used in Michigan. Can only be used on mineral soils. Classified by EPA as a C carcinogen.

3. **Pre-and post-emergence herbicides** (Used prior to or after weeds emerge)**:**
   - linuron (Lorox 50DF)

- Efficacy- E. Widely used as a necessary tool for early season weed management. Effective on most soil types. Fast acting and cost effective. One application of 2 pounds active ingredient per acre per year allowed. Some weeds have developed resistance to linuron. Minimal pre-emergence grass control and poor control of composites and wild carrot. However, there is good post-emergence activity on nutsedge, and is one of the few chemicals that can be used to control this weed. Toxic to fish and aquatic invertebrates. High potential for contaminating ground water. Classified by EPA as a C carcinogen.

- prometryn (Caparol 4L)
  - Efficacy- E. Widely used because of its residual and contact activity. Allowed 1-2 applications of 1-2 pounds per acre per year. Other main use is on cotton. Potential leaching and run-off concern. Although it is considered safer than linuron on celery, it has the same mode of action and may enhance development of weed resistance. Common purslane appears to have putative resistance. Potential toxicity to aquatic organisms.

4. **Post-emergence herbicides** (used to control weeds after they emerge)**:**
   - clethodim (Select Max 0.97E, Volunteer)
     - Efficacy- E. Very effective against small grain cover crops. Better than sethoxydim (Poast) on annual bluegrass, but weak on quackgrass and no broadleaf or yellow nutsedge control. There is potential for weeds to develop resistance. Toxic to Solano Grass and Wild Rice.
   - sethoxydim (Poast 1.5E)
     - Efficacy- G. Not used often because it is expensive. Weak on quackgrass and provides no broadleaf activity or yellow nutsedge control. There is potential for weeds to develop resistance. Toxic to aquatic organisms and non-target vascular plants.

Other pest management aids:
- Establishment of cover crops or wind breaks.
- Crop rotation with Roundup Ready™ soybeans/corn.
- Fall tillage.
- Cultivation.
- Hand weeding.

Pipeline pest management tools:
- Prowl H_2O
- Spartan – good selectivity on celery
- Goal Tender

"To do" list for weeds:
Research needs:
- More cost effective, safe herbicides needed for use in crop rotation to delay or prevent weed resistance.
- Control of common groundsel and other difficult weeds.

Regulatory needs:

- Registration of new products expedited as they become available.
- Partner with IR-4 to prioritize and move ahead with industry needs.
- Retain products that are already available.

Education needs:

- Best rotation of available products for resistance management.
- Updating knowledge on herbicide effectiveness against important weed pests.
- Staying up to date on weeds that are becoming resistant to herbicides.

VERTEBRATE PESTS

1. **Deer (*Odocoileus virginianus*) –** Deer can be an annual pest. Deer may eat entire plants and leave large bare patches where celery has been grazed. Grazing typically occurs near edges of woodlots but can occur in any portion of the field. Damage is often most significant in the fall when populations are largest.

   Pest Management Aids:

   - Fencing, but can be easily jumped if fence is too short.
   - Hunting during designated seasons. Increase of doe harvests and shooting permits.
   - Deer repellents.

   Research needs:

   - None.

   Regulatory needs:

   - Increased doe harvest.

   Education needs:

   - None.

TABLE 1. CLASSIFICATION OF PESTICIDES

Chemical group	Human Risk Assessment
Carbamate	Acetylcholinesterase inhibitor; disrupts the nervous system.
Organophosphate	Acetylcholinesterase inhibitor; disrupts the nervous system.
Neonicotinoid	Disrupts nervous system of insects.
Pyrethroid	Structure of chemical adopted from botanic derived chemicals.
Biopesticide	Pesticides developed from living organisms.
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 CELERY IN MICHIGAN

Active Ingredient	Trade name	Company
INSECTICIDES		
abamectin	Agri-Mek 0.15EC	Syngenta Crop Protection, Inc.
acephate	Acephate 97UP	United Phosphorus, Inc.
	Orthene 97	Amvac Chemical Corporation
acetamiprid	Assail 30SG	United Phosphorus, Inc.
Bacillus thuringiensis	Agree WG	Certis USA
	Biobit HP	Valent BioSciences Corporation
	Dipel	Valent BioSciences Corporation
	Javelin WG	Certis USA
	Xentari DF	Valent BioSciences Corporation
beta-cyfluthrin	Baythroid XL	Bayer CropScience
carbaryl	10% Sevin granules	Loveland Products
	Sevin 4F	Bayer CropScience
	Sevin 80WSP	Bayer CropScience
	Sevin XLR Plus	Bayer CropScience
chlorantraniliprole	Coragen	DuPont Agricultural Products
clothianidin	Belay	Valent Corporation
cyromazine	Trigard	Syngenta Crop Protection, Inc.
dimethoate	Dimethoate 2.67EC	Loveland Products, Inc.
	Dimethoate 4EC	Helena Chemical Company
	Dimethoate 4E	Cheminova, Inc.
dinotefuran	Scorpion 35SL	Gowan Company
	Venom	Valent USA Corporation
	Venom 20SG	Valent USA Corporation
emamectin benzoate	Proclaim	Syngenta Crop Protection Inc.
endosulfan	Endosulfan 3EC	Drexel Chemical Co.
	Thionex 3EC	Makhteshim Agan
	Thionex 50W	Makhteshim Agan
flonicamid	Beleaf 50SG	FMC Corporation
flubendiamide	Synapse WG	Bayer CropScience
flubendiamide/buprofezin	Vetica	Nichino America Inc.
imidacloprid	Admire PRO	Bayer CropScience
	Nuprid 2F	Nufarm Americas Inc.
	Alias	Makhteshim Agan
indoxacarb	Avaunt	DuPont Agricultural Products
malathion	Malathion 5	Winfield Solutions, LLC
	Malathion 5EC	Micro Flo Company LLC
	Malathion 57EC	Loveland Products, Inc.
	Malathion 8	Gowan Company
methomyl	Lannate LV	DuPont Agricultural Products
	Lannate SP	DuPont Agricultural Products
methoxyfenozide	Intrepid 2F	Dow AgroSciences
neem oil	Trilogy	Certis USA L.L.C.
oxamyl	Vydate L	DuPont Agricultural Product
permethrin	Ambush 25W	Amvac Chemical Corporation
	Perm-UP 25DF	United Phosphorus Inc.

Active Ingredient	Trade name	Company
	Perm-UP 3.2EC Pounce 25WP	United Phosphorus Inc. FMC Corporation
pymetrozine	Fulfill	Syngenta Crop Protection, Inc.
pyrethrin/piperonyl butoxide	Pyrenone	Multiple manufacturers
pyrethrin/rotenone	Pyrellin EC	Webb Wright Corp.
spinetoram	Radiant SC	Dow AgroSciences
spinosad	Entrust	Dow AgroSciences
spirotetramat	Movento	Bayer CropScience
tebufenozide	Confirm 2F	Dow AgroSciences
thiamethoxam	Actara Platinum Platinum 75SG	Syngenta Crop Protection, Inc.
thiamethoxam/chlorantraniliprole	Durivo Voliam Flexi	Syngenta Crop Protection, Inc.
zeta-cypermethrin (2S)	Mustang Max	FMC Corporation
NEMATICIDES		
1,3-dichloropropene	Telone II	Dow AgroSciences
metam	Vapam Sectagon	AMVAC TKI. Inc.
oxamyl	Vydate	DuPont Agricultural Product
MITICIDES & MOLLUSCICIDES		
abamectin	Agri-Mek 0.15EC	Syngenta Crop Protection, Inc.
dimethoate	Dimethoate 2.67 EC Dimethoate 4EC Dimethoate 4E	Loveland Products, Inc. Helena Chemical Co. Cheminova, Inc.
malathion	Malathion 5 Malathion 5EC Malathion 57EC Malathion 8	Winfield Solutions, LLC Micro Flo Company LLC Loveland Products, Inc. Gowan Company
metaldehyde	Deadline M-Ps Metaldehyde 3.5G	Amvac Chemical Corporation
neem oil	Trilogy	Certis USA L.L.C.
FUNGICIDES		
azoxystrobin	Quadris	Syngenta Crop Protection, Inc.
azoxystrobin/chlorothalonil	Quadris Opti	Syngenta Crop Protection, Inc.
azoxystrobin/propiconazole	Quilt Quilt Xcel	Syngenta Crop Protection, Inc.
chlorothalonil	Bravo Ultrex Bravo Weather Stik Equus DF Equus 720SST Echo 90DF Echo 720 Echo Zn	Syngenta Crop Protection, Inc. Syngenta Crop Protection, Inc. Makhteshim Agan Makhteshim Agan Sipcam Agro USA, Inc. Sipcam Agro USA, Inc. Sipcam Agro USA, Inc.
copper ammonium carbonate	Copper Count N	Mineral Research & Development Corp.

Active Ingredient	Trade name	Company
copper hydroxide	Champ Formula 2F	Nufarm Americas, Inc.
	Champ DP	Nufarm Americas, Inc.
	Champion WP	Nufarm Americas, Inc.
	Kocide 2000	DuPont
	Kocide 3000	DuPont
	Nu-Cop 3L	Albaugh Inc.
	Nu-Cop 50DF	Albaugh Inc.
copper oxychloride/copper sulfate	C-O-C-S WDG	Loveland Products, Inc.
copper sulfate	Basic Copper 53	Albaugh Inc.
	Cuprofix Ultra	Cerexagri-Nisso L.L.C.
cyprodinil/fludioxonil	Switch 62.5WG	Syngenta Crop Protection, Inc.
DCNA	Botran 75W	Gowan Company
fenamidone	Reason 500SC	Bayer CropScience
mefenoxam	Ridomil Gold GR	Syngenta Crop Protection, Inc.
	Ridomil Gold SL	Syngenta Crop Protection, Inc.
	Ultra Flourish	Nufarm Americas Inc.
neem oil	Trilogy	Certis USA
potassium phosphite/chlorothalonil	Catamaran	Luxembourg-Pamol, Inc.
propiconazole	Propimax EC	Dow AgroSciences
	Tilt	Syngenta Crop Protection, Inc.
pyraclostrobin	Cabrio	BASF Corporation
trifloxystrobin	Flint	Bayer CropScience
	Gem 500	Bayer CropScience
HERBICIDES		
clethodim	Select	Valent USA Corporation
	Volunteer	Tenkoz, Inc.
flumioxazin	Chateau WDG	Valent USA Corporation
glyphosate	Round-up	Monsanto Company
linuron	Lorox DF	Tessenderlo-Kerley, Inc.
metolachlor	Dual Magnum	Syngenta Crop Protection, Inc.
prometryn	Caparol 4L	Syngenta Crop Protection, Inc.
sethoxydim	Poast	BASF Corporation
trifluralin	Treflan	Dow AgroSciences

TABLE 3. DESCRIPTION OF PESTS AND PATHOGENS OF CELERY

Pest/Pathogen	Symptoms
INSECT PESTS	
Aphids (green peach aphid *Myzus persicae* and other aphids)	Numbers depend on seasonal conditions, location and control program. When abundant, they cause leaf distortion. Presence of their molted skins and honeydew can make celery unmarketable.
Aster leafhopper (*Macrosteles quadrilineatus*)	Economically important pest because it is the vector of the aster yellows disease.
Carrot weevil (*Listronotus oregonensis*)	Adults puncture and lay one to several eggs in the petioles of the celery. Larvae either tunnel in the petiole or move to the crown or roots to feed. Celery transplants are susceptible from the time of planting. Injury varies with the number of weevils present and in extreme cases, when soil moisture is low, severe wilting can occur due to reduced root mass.
Cutworms (Noctuidae)	Damage is primarily due to feeding on petioles.
Celery leaftier (*Udea rubigalis*)	A sporadic problem. Because of their size it is often difficult to detect unless population sizes are large.
Loopers (celery looper (*Anagrapha falcifera*) and cabbage looper (*Trichoplusia ni*))	Along with cutworms, these caterpillars can occasionally be a problem, however, the outer stalks that might be damaged in this way are usually removed prior to market.
Tarnished plant bug (*Lygus lineolaris*)	A pest on many fruit and vegetable crops, as well as alfalfa. Adults feeding early in the season may not be important since marketable petioles are not present. However, damage near harvest (commonly called black joint) can be confused with black heart, a physiological disorder resulting from calcium deficiency. Damage to petioles can cause celery to be rejected and in extreme cases can lead to petiole death due to secondary organisms coming in on the wounds. It only takes a few petioles damaged to this extent to make the entire plant unmarketable.
Vegetable leaf miner (Agromyzidae)	An occasional problem in some areas, damage is mainly cosmetic. However, severe infestations can cause wilting when conditions are dry.
Wireworms (Elateridae)	Beetle larvae can occasionally be a problem. Their feeding via tunneling will damage petioles.

Pest/Pathogen	Symptoms
NEMATODE PESTS	
Northern root-knot nematode (*Meloidogyne hapla*)	Root-knot nematodes can severely reduce celery quality and yields by causing galls, forking and bunching
Pin nematode (*Paratylenchus hamatus*)	Severe infestations can cause wilting, stunting and yellowing of leaves and petioles.
Needle nematode (*Longidorus elongatus*)	Severe infestations can cause wilting, stunting and yellowing of leaves and petioles.
Root-lesion nematode (*Pratylenchus penetrans*)	Symptoms include wilting and stunting in patches of heavy infestation, yellowing leaves, and necrotic secondary roots with dry patches.
OTHER INVERTEBRATE PESTS	
Slugs	Feeding damage from slugs is occasionally a problem.
Spider mites (Acari)	Numbers depend on seasonal conditions, location and control program. When abundant, they cause leaf distortion and unsightly webbing.
PATHOGENS	
Bacterial blight (*Pseudomonas syringae* pv. *apii*)	Small, bright yellow, circular spots, 1 to 2 mm in diameter first occur on the leaves and later enlarge, turn rusty brown and usually are surrounded by a yellow halo. Numerous spots can give a blighted appearance.
Soft rot (*Erwinia carotovora*)	Affected areas appear water-soaked, develop a soft decay and have a distinctive foul odor. Infection occurs through wounds or other injured areas. Warm wet conditions promote disease development.
Crater rot (*Rhizoctonia solani*)	Causes brown, oval, sharply delineated tan to brown lesions on the exterior of the outer petioles.
Damping off (*Pythium* sp. and *Rhizoctonia solani*)	Diseases caused by several fungi. Damping off occurs when infected seedlings wilt, turn brown and die, or develop water soaked, discolored stem at ground level and topple over, resulting in poor stands.
Foliar blight (*Cercospora apii* and *Septoria apiicola*)	*Cercospora apii* first appears as yellow spots visible on both sides of the foliage. These spots enlarge rapidly, become ashen-gray and do not have a distinct margin. *Septoria apiicola* looks very similar; however it has very small, widely separated back pycnidia within the spots. Both blights infect the leaves and petioles.

Pest/Pathogen	Symptoms
Fusarium yellows (*Fusarium oxysporum* f. sp. *apii*)	Plants tend to be brittle, stunted, yellow and taste bitter. As disease progresses, the crown and roots rot.
White or pink mold (*Sclerotinia sclerotiorum*)	Causes damping-off in infested seedbeds. Characterized by rapid development of basal crown and petiole rot. Plants appear to suddenly wilt and collapse in the field. Rotted area is watery, pinkish, and in moist conditions may become covered with white mold, which contains hard black sclerotia.
Anthracnose (*Colletotrichum acutatum*)	Found in celery fields in 2010 but has not been confirmed in Michigan previously. Causes leaves to cup and brown slender lesions form along the petioles. Cracking has been found in some infections, however it is unknown if this symptom is actually caused by the disease. Little is known about this disease in Michigan.

TABLE 4. ADVANTAGES AND DISADVANTAGES OF PESTICIDES FOR CELERY

Active ingredient	Disease/Pest	Advantages/Disadvantages
INSECTICIDES		
abamectin	Spider mites Vegetable leafminer	• RUP; ground application only • highly effective against leafminer larvae • fits well into an IPM program because it is less disruptive to beneficial insects • resistance management concerns • expensive • potential toxicity to amphibians, crustaceans and non-target insects
acetamiprid	Aphids	• reduced risk pesticide • organophosphate alternative • toxic to bees and wildlife
acephate	Aphids Aster leafhopper Loopers	• systemic • on EPA Phase 1 list; organophosphate • frequently used in resistance rotation • long PHI=21 days; not used at harvest • concerns about beneficial insects • only two applications per year allowed • toxic to birds and bees • C carcinogen
Bacillus thuringiensis	Celery leaftier Loopers	• limited effectiveness • slow acting; insect must ingest for activity • very safe; no pre-harvest interval • limited residual activity • biopesticide • toxic to non-target *Lepidoptera*, green lacewing, and predatory mites
beta-cyfluthrin	Aster leafhopper Celery leaftier Loopers Tarnished plant bug	• PHI = 0 days. • restricted use pesticide • toxic to bees, fish, and aquatic invertebrates
carbaryl	Aster leafhopper Cutworms Tarnish plant bug	• on EPA Phase 1 list; carbamate • used on multiple crops; inexpensive and effective • broad spectrum, hard on beneficials • resistance issues • some processors will not accept it • toxic to bees and aquatic invertebrates • B2 carcinogen
chlorantraniliprole	Cutworms Celery leaftier Loopers Vegetable leafminer	• reduced risk pesticide • PHI = 1 day • toxic to aquatic invertebrates • concern for ground water contamination
clothianidin	Aphids Aster leafhopper	• concern for ground water contamination • toxic to bees and aquatic invertebrates

Active ingredient	Disease/Pest	Advantages/Disadvantages
		• PHI = 21 days
cyromazine	Vegetable leafminer	• less harmful to beneficials • used in resistance management programs • effective, but highly toxic to aquatic organisms • expensive, multiple applications necessary and slow acting • concern for ground water contamination • E chemical
dimethoate	Aphids Vegetable leafminer Spider mites	• on EPA phase 1 list: organophosphate • concern for ground water contamination • toxic to wildlife, aquatic invertebrates, and bees • C carcinogen
dinotefuran	Aphids Aster leafhopper Vegetable leafminer	• reduced risk pesticide • organophosphate alternative • toxic to bees and shrimp • concern for ground water contamination
emamectin benzoate	Loopers	• ground or aerial application • good efficacy
endosulfan	Aphids Aster leafhopper Loopers	• tolerance revoked; cannot use after July 2012 • organochlorine; highly toxic to fish and corrosive on iron • one application allowed per year • short pre-harvest interval = 4 days • limited efficacy, used in resistance management • toxic to bees and shrimp • restricted use pesticide
flonicamid	Aphids Tarnished plant bug	• organophosphate alternative • selective; not as harmful to beneficials • slow to control • early season control; insects found in harvested celery • PHI = 0 days • D carcinogen
flubendiamide	Cutworms	• PHI = 1 day • toxic to aquatic invertebrates
flubendiamide/buprofezin	Cutworms Celery leaftier Loopers	• toxic to aquatic invertebrates • D carcinogen
imidacloprid	Aphids Aster leafhopper	• systemic soil treatment • concern for ground water contamination • toxic to bees • PHI = 45 days • E chemical
indoxacarb	Loopers	• reduced risk pesticide • PHI = 3 days

Active ingredient	Disease/Pest	Advantages/Disadvantages
		• toxic to bees, birds, mammals, fish, and aquatic invertebrates
malathion	Aphids Spider mites	• on EPA Phase 1 list; organophosphate • used in resistance management programs • losing effectiveness in some areas • toxic to bees, birds, fish, amphibians and other aquatic organisms • D carcinogen
methomyl	Aphids Aster leafhopper Cutworms Loopers Tarnished plant bug	• on EPA Phase 1 list; carbamate • broad spectrum; short residual • used in resistance management programs • short pre-harvest interval = 7 days • expensive, but very effective • restricted use pesticide • toxic to birds, bees, mammals, fish and aquatic invertebrates • concern for ground water contamination • E chemical
methoxyfenozide	Cutworms Loopers	• reduced risk pesticide • organophosphate alternative • potential toxicity to aquatic invertebrates • PHI = 1 day
neem oil	Aphids Spider mites Cercospera early blight	• efficacy data and use pattern lacking • biopesticide • toxic to bees, fish, and aquatic invertebrates
oxamyl	Carrot weevil Nematodes	• on EPA Phase 1 list; carbamate • 24C in Michigan for use against carrot weevil larvae • systemic used in resistance management • expensive • only insecticide registered for control of carrot weevil larvae • toxic to bees, aquatic invertebrates, birds, fish, and mammals • concern for ground water contamination • very good efficacy for carrot weevil • E chemical
permethrin	Aphids Aster leafhopper Loopers Tarnished plant bug Vegetable leafminer	• used in resistance management programs • broad spectrum; may reduce beneficial insects and increase aphid populations • inexpensive • pre-harvest interval = 1 day • toxic to bees, fish, and aquatic invertebrates • B2 carcinogen • restricted use pesticide
pymetrozine	Aphids	• paralyzes aphid mouth parts; slower control time

Active ingredient	Disease/Pest	Advantages/Disadvantages
		• early season control; insects found in harvested celery • B2 carcinogen
pyrethrin/piperonyl butoxide	Aphids Aster leafhopper Cutworms Celery leaftier Loopers Carrot Weevil Vegetable leafminer	• may increase aphid populations • no pre-harvest interval • non-toxic to humans and animals • minimally disruptive to beneficials • short residual • only 1-3 applications per season • not readily available in Michigan • C carcinogen • toxic to fish
pyrethrin/rotenone	Aphids Aster leafhopper Celery leaftier Loopers Vegetable leafminer	• may increase aphid populations • hard on beneficials • toxic to fish • PHI = ½ day
spinetoram	Loopers Vegetable leafminer	• reduced risk pesticide • toxic to bees and aquatic invertebrates • PHI = 1 day
spinosad	Loopers Vegetable leafminer	• used in resistance management programs • expensive • short pre-harvest interval = 1 day • toxic to bees and aquatic invertebrates • reduced risk pesticide
spirotetramat	Aphids	• reduced risk pesticide • toxic to aquatic invertebrates and potential toxicity to bee larvae • PHI = 3 days.
tebufenozide	Loopers	• insect growth regulator; safe around beneficials • activity specific to Lepidoptera • expensive • reduced risk pesticide • organophosphate alternative • E chemical
thiamethoxam	Aphids Aster leafhopper	• toxic to bees, wildlife and aquatic invertebrates • concern for ground water contamination
thiamethoxam/ chlorantraniliprole	Aphids Aster leafhopper Loopers Vegetable leafminer	• expensive • toxic to bees, birds, oyster, shrimp, and wildlife. • concern for ground water contamination
zeta-cypermethrin (2S)	Aster leafhopper Cutworms Celery leaftier Loopers Tarnished plant bug	• organophosphate alternative • PHI = 1 day • Toxic to bees, fish, and aquatic invertebrates • C carcinogen • restricted use pesticide

Active ingredient	Disease/Pest	Advantages/Disadvantages
	Wireworm	
NEMATICIDES		
dichloropropene	Nematodes	• on EPA Phase 1 list; B1 or B2 carcinogen • fumigant • expensive • specific temperature requirements limit its use in Michigan • restricted use pesticide • concern for ground water contamination
metam	Nematodes	• on EPA Phase 1 list; B1 or B2 carcinogen • expensive • fumigant • used in other crops in Michigan, but not much in celery • also good against soil-borne diseases • toxic to fish • restricted use pesticide
oxamyl	Carrot weevil Nematodes	• on EPA Phase 1 list; carbamate • must be applied in low rate, multiple applications for efficacy • systemic used in resistance management • some resistance concerns • may be applied through trickle irrigation • expensive • toxic to bees, birds, fish, and aquatic invertebrates • concern for ground water contamination • restricted use pesticide • E chemical
MITICIDES & MOLLUSCICIDES		
abamectin	Spider mites Vegetable leafminer	• RUP; ground application only • highly effective against leafminer larvae • fits well into an IPM program because it is less disruptive to beneficial insects • resistance management concerns • expensive • toxic to bees, mammals, and fish • potential toxicity to amphibians, crustaceans, and non-target insects • very good efficacy in spider mites
dimethoate	Aphids Spider mites	• on EPA phase 1 list: organophosphate • concern for ground water contamination • toxic to wildlife, aquatic invertebrates, and bees • C carcinogen
malathion	Aphids Spider mites	• on EPA Phase 1 list; organophosphate • used in resistance management programs • losing effectiveness in some areas

Active ingredient	Disease/Pest	Advantages/Disadvantages
		• C carcinogen • toxic to bees, birds, fish, amphibians, and other aquatic organisms.
metaldehyde	Slugs	• must avoid contact with plants • used between rows • C carcinogen
neem oil	Aphids Spider mites Cercospera early blight	• efficacy data and use pattern lacking • biopesticide • toxic to bees, fish, and aquatic invertebrates. • PHI = 0 days.
FUNGICIDES		
azoxystrobin	Crater Rot Cercospora early blight Septoria late blight Anthracnose	• higher cost than protectant fungicides • broad spectrum, locally systemic • must be used in resistance management programs • highly toxic to fish and aquatic invertebrates • nontoxic to bees, mammals and birds • reduced risk pesticide • PHI = 0 days
azoxystrobin/chlorothalonil	Crater Rot Cercospora early blight Septoria late blight	• on EPA Phase 1 list; B2 carcinogen • highly toxic to fish and aquatic invertebrates • nontoxic to bees • very effective • toxic to fish, aquatic invertebrates and wildlife • concern for ground water contamination
azoxystrobin/propiconazole	Cercospora early blight Septoria late blight	• only four applications allowed per season • used in resistance management programs • long residual • variable efficacy • highly toxic to fish and aquatic invertebrates • nontoxic to bees, mammals and birds • concern for ground water contamination • C carcinogen
chlorothalonil	Crater rot Cercospora early blight Septoria late blight White or pink mold Anthracnose	• on EPA Phase 1 list; B2 carcinogen • broad spectrum foliar protectant • inexpensive, cost effective • most important tool against foliar blights in Michigan • very effective • used in resistance management programs • toxic to aquatic invertebrates and wildlife • concern for groundwater contamination
copper ammonium carbonate copper hydroxide copper oxychloride copper sulfate	Bacteria blight Cercospora early blight Septoria late blight	• inexpensive • toxic to fish and aquatic organisms • limited efficacy under significant disease pressure from Cercospora early blight and Septoria late blight • broad spectrum bactericide/fungicide

Active ingredient	Disease/Pest	Advantages/Disadvantages
		• not effective alone, must be used in rotation • pre-harvest interval = 0 days
cyprodinil/fludioxonil	White or pink mold	• PHI = 0 days • toxic to fish and aquatic organisms • concern for ground water contamination • D carcinogen
DCNA	Crater rot White or pink mold	• effective, but expensive • specific to sclerotia-forming fungi; may also be effective on other soil borne pathogens • not widely available in Michigan • toxic to fish
fenamidone	Septoria late blight	• fair to poor on Cercospera blight • reduced risk • toxic to aquatic invertebrates and fish • PHI = 2 days
mefenoxam	Damping off	• resistance concerns • long residual • expensive • not registered for greenhouse • concern for ground water contamination
neem oil	Aphids Spider mites Cercospera early blight	• efficacy data and use pattern lacking • biopesticide • toxic to bees, fish, and aquatic invertebrates
potassium phosphite / chlorothalonil	Crater Rot Cercospora early blight Septoria late blight	• on EPA Phase 1 list; B2 carcinogen • effective on foliar pathogens • both active ingredients listed for greenhouse • toxic to aquatic invertebrates and wildlife
propiconazole	Cercospora early blight Septoria late blight	• only four applications allowed per season • used in resistance management programs • long residual • variable efficacy • may have growth regulator effects • toxic to fish • C carcinogen
pyraclostrobin	Cecospera leaf spot Septoria leaf spot Anthracnose	• very good control on cercospera and septoria leaf blights • reduced risk • toxic to fish and aquatic invertebrates • PHI = 0 days
trifloxystrobin	Cercospora early blight Septoria late blight	• very good control on cercospera and septoria leaf blights • reduced risk pesticide • toxic to fish and aquatic invertebrates • concern for ground water contamination
HERBICIDES		
clethodim	Grasses	• excellent efficacy • important grass herbicide

Active ingredient	Disease/Pest	Advantages/Disadvantages
		• effective against annual grasses and clearing fields of cover crops • weak on quackgrass • no broadleaf or yellow nutsedge control • inexpensive • potential resistance issues • toxic to solano grass and wild rice
flumioxazin	Annuals	• very-good efficacy • good pre-emergence activity on most weeds • weak on horseweed (marestail) • toxic to aquatic invertebrates and non-target plants
glyphosate	Grasses Broadleaf weeds	• very good efficacy • no pre-harvest interval • broad spectrum, excellent on perennials • no residual activity • mildly toxic to birds • non-toxic to aquatic organisms • reduced risk pesticide • cannot be used during production • E chemical
linuron	Grasses Broadleaf weeds	• excellent efficacy • C carcinogen • broad spectrum on annuals • some resistance issues • effective on most soil types • fast acting and cost effective • one application allowed per season • no control over composites, wild carrot and nutsedge • toxic to fish and aquatic invertebrates • concern for ground water contamination
metolachlor	Grasses	• 24C in Michigan because of concerns about breakdown products – undergoing EPA cumulative assessment • one of the few products effective against nutsedge • short residual • high rates needed on muck soils • C carcinogen • concern for ground water contamination
prometryn	Grasses Broadleaf weeds	• excellent efficacy • only one-two applications allowed per year • long pre-harvest interval = 45 days • long residual activity • also used on cotton • potential groundwater concerns • resistance concerns due to same mode of action as linuron

Active ingredient	Disease/Pest	Advantages/Disadvantages
		• E chemical
sethoxydim	Grasses	• important grass herbicide • not effective at temperatures less than 60F • long pre-harvest interval = 30 days • weak on quackgrass • no broadleaf or yellow nutsedge control • expensive • resistance concerns • toxic to aquatic organisms and non-target vascular plants
trifluralin	Grasses Broadleaf weeds	• C carcinogen • limited efficacy especially on muck soils • one application allowed per year • short residual • inexpensive • kills weed seeds • rainfall not required for activity • may cause phytotoxicity

TABLE 5: ADVANTAGES AND DISADVANTAGES OF NON-CHEMICAL PEST MANAGEMENT TOOLS

Management	Disease/Pest	Advantages/Disadvantages
Avoid planting legumes	Nematodes	• planting legumes increases root-knot nematode populations
Avoid planting near small grains or other susceptible vegetable crops	Aster leafhopper	• sometimes unavoidable
Awareness of nearby activities (hay harvesting, other crops)	Aster leafhopper Tarnished plant bug	• not a control mechanism • provides an indicator of when to implement control strategies
Cover crop - Brassica	Weeds Disease	• protection from wind erosion • natural inhibitor of some pests; biofumigant
Cover crop - Mustard	Weeds Diseases	• protection from wind erosion
Cover crop – Oilseed Radish	Weeds Nematodes	• protection from wind erosion • effective for weed control • most effective post-harvest • uncertain if a host for *Rhizoctonia*; then becomes pest in celery
Cover crop – Rye	Weeds Fusarium	• protection from wind erosion • potentially stunt celery
Crop rotation	Bacterial blight Carrot weevil Damping off Fusarium yellows	• uncertainty regarding the efficacy of using edible crops in rotation with celery • not a stand alone tool for Fusarium yellows management
Greenhouse cultural management	Bacterial blight Damping off	• cost effective method for reducing population sizes
Pheromone traps	Loopers	• cost effective method for scouting
Planting times	Black streak	• disease caused by warmer temperatures • transplant during cooler times of the growing season • Duchess variety most susceptible to black streak
Plant spacing	Disease Insects Black streak	• spacing dictated according to market; large spacing for fresh, small spacing for processing
Plow down green manure crops	Nematodes	• increase soil productivity • green manure crop helps conserve top-soil • some cover crops may increase

Management	Disease/Pest	Advantages/Disadvantages
		populations (legumes)
Predatory mites	Spider mites	• natural predator populations are not enough to control mites alone
Post-harvest tilling	Bacterial blight Foliar leaf blights	• reduces populations by speeding up the breakdown of plant debris
Raised beds	Disease	• reduce the effects of flooding • decreases celery density, but increases average size of celery
Resistant cultivars (Duchess, Sabroso, Greenbay)	Fusarium yellows	• horticultural characteristics not yet achieved; need larger and taller petioles • Duchess variety not very resistant to *Fusarium*
Soil drainage	Damping off	• prevents developing optimal conditions for pathogen growth
Water & nutrient management	Fusarium yellows	• increase resistance by reducing plant stress
Weed control	Aster leafhopper Tarnished plant bug	• reduces populations by removing feeding sources

TABLE 6. EFFICACY OF PEST MANAGEMENT TOOLS FOR CONTROL OF INSECT AND OTHER INVERTEBRATE PESTS ON CELERY IN MICHIGAN

Management tool	Insect pests of celery[1]										
	Aphids	AL	Carrot weevil	CW	CL	LP	TPB	VLM	WW	SM	Slugs
Organophosphate insecticides registered											
acephate (Acephate 97 UP, Orthene 97)	G	G	-	-	-	G	G	-	-	-	-
dimethoate (Dimethoate 2.67EC, Dimethoate 4EC, Dimethoate 4E)	F	-	-	-	-	-	-	-	-	F	-
malathion (Malathion)	NA	-	-	-	-	-	-	-	-	NA	-
Carbamate insecticides registered											
carbaryl (Sevin)	-	G	-	F	-	-	G	-	-	-	-
methomyl (Lannate)	G	G	-	G	-	G	G	-	-	-	-
oxamyl (Vydate L)	-	-	VG**	-	-	-	-	-	-	-	-
Neonicotinoid insecticides registered											
acetamiprid (Assail 30 SG)	G	-	-	-	-	-	-	-	-	-	-
clothianidin (Belay)	NA	NA	-	-	-	-	-	-	-	-	-
dinotefuran (Scorpion, Venom)	NA	NA	-	-	-	-	-	NA	-	-	-
imidacloprid (Admire Pro, Nuprid 2 F, Alias)	G	F	-	-	-	-	G	-	-	-	-
thiamethoxam (Actara, Platinum)	G	NA	-	-	-	-	-	-	-	-	-
thiamethoxam/chlorantraniliprole (Durivo, Voliam Flexi)	G	NA	-	-	-	NA	-	NA	-	-	-
Pyrethroid insecticides registered											
beta-cyfluthrin (Baythroid XL)	-	G	-	-	NA	G	NA	-	-	-	-
permethrin (Ambush, Perm-UP, Pounce)	NC	G	-	-	-	G	G	NA	-	-	-

Management tool	Insect pests of celery[1]										
	Aphids	AL	Carrot weevil	CW	CL	LP	TPB	VLM	WW	SM	Slugs
pyrethrin/piperonyl butoxide (Pyrenone)*	NC	NA	NA	NA	NA	G	-	NA	-	-	-
pyrethrin/rotenone (Pyrellin)*	NC	NA	-	-	NA	G	-	NA	-	-	-
zeta-cypermethrin 2S (Mustang Max)	-	G	-	G	NA	G	G	-	NA	-	-
Biopesticides registered											
Bacillus thuringiensis (many trade names)	-	-	-	-	NA	NA	-	-	-	-	-
neem oil (Trilogy)	NA	-	-	-	-	-	-	-	-	NA	-
Other insecticides registered											
abamectin (Agri-Mek 0.15 EC)	-	-	-	-	-	-	-	G	-	VG	-
chlorantraniliprole (Coragen)	-	-	-	NA	NA	F	-	NA	-	-	-
cyromazine (Trigard)	-	-	-	-	-	-	-	G	-	-	-
emamectin benzoate (Proclaim)	-	-	-	-	-	G	-	-	-	-	-
endosulfan (Endosulfan, Thionex)	G	NA	-	-	-	G	-	-	-	-	-
flonicamid (Beleaf 50 SG)	G	-	-	-	-	-	G	-	-	-	-
flubendiamide (Synapse WG)	-	-	-	NA	-	-	-	-	-	-	-
flubendiamide/buprofezin (Vetica)	-	-	-	NA	NA	NA	-	-	-	-	-
indoxacarb (Avaunt)	-	-	-	-	-	NA	-	-	-	-	-
metaldehyde (Deadline, Metaldehyde)	-	-	-	-	-	-	-	-	-	-	NA
methoxyfenozide (Intrepid 2 F)	-	-	-	NA	-	NA	-	-	-	-	-
pymetrozine (Fulfill)	NC	-	-	-	-	-	-	-	-	-	-
spinetoram (Radiant SC)	-	-	-	-	-	NA	-	NA	-	-	-

Management tool	Insect pests of celery[1]										
	Aphids	AL	Carrot weevil	CW	CL	LP	TPB	VLM	WW	SM	Slugs
spinosad (Entrust)	-	-	-	-	-	NA	-	NA	-	-	-
spirotetramat (Movento)	NA	-	-	-	-	-	-	-	-	-	-
tebufenozide (Confirm)	-	-	-	-	-	NA	-	-	-	-	-
Cultural controls											
avoid planting near small grains	-	NA	-	-	-	-	-	-	-	-	-
awareness of nearby activities (ex. hay harvesting)	-	-	-	-	-	-	NA	-	-	-	-
crop rotation	-	-	NA	-	-	-	-	-	-	-	-
infectivity index for assessing threshold	-	NA	-	-	-	-	-	-	-	-	-
pheromone traps	-	-	-	NA	-	NA	-	-	-	-	-
predatory mites	-	-	-	-	-	-	-	-	-	P	-
weed control	-	NA	-	-	-	-	NA	-	-	-	-
Pipeline pest management tools											
Biologicals	NA	-	-	-	-	-	-	-	-	-	-

** effective on larvae

[1] Insect abbreviations: AL = aster leafhoppers, CW = cutworms, CL = celery leaftier, LP = loopers, TPB = tarnish plant bugs, VLM = vegetable leaf miner, WW = wireworms, SM = spider mites.

[2] Includes celery and cabbage loopers.

[3] Efficacy rating symbols: E = excellent (98-100% control), VG= very good (90-98% control), G = good (85-90% control), F = fair (80-85%), P = poor (<80% control), NA = no data available, - = not applicable and/or used, NC = no control – using this management method may increase problems with this pest.

TABLE 7. EFFICACY OF PEST MANAGEMENT TOOLS FOR CONTROL OF NEMATODE PESTS ON CELERY IN MICHIGAN

Management tool	Nematode pests of celery			
	needle	pin	northern root-knot	root-lesion
Carbamate nematicides registered				
oxamyl (Vydate)				
pre-plant application	P	NA	F	F
planting application	P	NA	F	G
post-plant application	P-F	NA	VG	V
Other nematicides registered				
1,3-dichloropropene (Telone II)	[1]E	G	E	E
metam (Vapam, Sectagon)	NA	NA	G	E
Cultural controls				
legumes	-	-	NC	-
crop rotation	G	NA	G	P
plow down green manure crops	NA	NA	NA	NA
Pipeline pest management tools				
conditioner, trap and nematicidal crops, nonhost crops, new nematicides	NA	NA	G	G
Seed treatments (Evicta, Botiva, Pasteuria)	NA	NA	NA	NA
Soil quality	NA	NA	NA	NA

Management tool	Nematode pests of celery			
	needle	pin	northern root-knot	root-lesion
Bacillus firmus	NA	NA	NA	NA
Biofumigation	NA	NA	NA	NA

[1] Efficacy rating symbols: E = excellent (98-100% control), VG= very good (90-98% control), G = good (85-90% control), F = fair (80-85%), P = poor (<80% control), NA = no data available, - = not applicable and/or used, NC = no control – using this management method may increase problems with this pest.

TABLE 8. EFFICACY OF PEST MANAGEMENT TOOLS FOR CONTROL OF DISEASES ON CELERY IN MICHIGAN

Management tool	Diseases of celery[1]							
	BB	SR	CR	DO	FB	FY	WM	AN
Biopesticides registered in MI								
neem oil (Trilogy)	-	-	-	-	P	-	-	-
Other fungicides registered in MI								
azoxystrobin (Quadris)	-	-	VG	-	VG	-	-	NA
azoxystrobin/chlorothalonil (Quadris Opti)	-	-	NA	-	VG	-	-	-
azoxystrobin/propiconazole (Quilt, Quilt Xcel)	-	-	G	-	E	-	-	-
chlorothalonil (Bravo, Echo)	-	-	F	-	E	-	NA	NA
copper ammonium carbonate (Copper Count N)	F	-	-	-	P	-	-	-
copper hydroxide (Champ, Champion, Kocide, Nu-Cop)	F	-	-	-	F	-	-	-
copper oxychloride/copper sulfate (C-O-C-S WDG)	F	-	-	-	P	-	-	-
copper sulfate (Basic Copper 53, Cuprofix Ultra, Basicop 53 WP)	F	-	-	-	P	-	-	-
cyprodinil/fludioxonil (Switch 62.5 WG)	-	-	-	-	-	-	NA	-
DCNA (Botran 75W)	-	-	F	-	-	-	NA	-
fenamidone (Reason 500 SC)	-	-	-	-	P	-	-	-
mefenoxam (Ridomil Gold, Ultra Flourish)	-	-	-	G	-	-	-	-
potassium phosphite/chlorothalonil (Catamaran)	-	-	P	-	F	-	-	-

Management tool	Diseases of celery[1]							
	BB	SR	CR	DO	FB	FY	WM	AN
propiconazole (Tilt)	-	-	-	-	G	-	-	-
pyraclostrobin (Cabrio)	-	-	-	-	VG	-	-	NA
trifloxystrobin (Flint, Gem 500)	-	-	-	-	VG	-	-	-
Cultural controls								
crop rotation	NA	-	-	NA	-	NA	-	-
greenhouse cultural management	NA	-	-	NA	-	-	-	-
keep equipment clean	NA	-	-	NA	-	-	-	-
keep soil off of crown	-	-	NA	-	-	-	-	-
plant certified and tested seed	-	-	-	-	NA	-	-	-
post-harvest tilling	NA	-	-	-	NA	-	-	-
raised beds	-	-	NA	-	-	-	-	-
resistant cultivars	-	-	-	-	-	NA	-	-
soil drainage	-	-	-	NA	-	-	-	-
treated seed (hot water)	NA	-	-	-	-	-	-	-
water and nutrient management	-	-	-	-	-	NA	-	-
Pipeline pest management tools								
Inspire	-	-	NA	-	NA	-	-	-
Fontellis	-	-	-	-	NA	-	-	-
Luna	-	-	NA	-	NA	-	-	-

Management tool	Diseases of celery[1]							
	BB	SR	CR	DO	FB	FY	WM	AN
Tanos	-	-	-	-	VG	-	-	-
Presidio	-	-	-	NA	-	-	-	-
Ranman	-	-	-	NA	-	-	-	-
Previcur Flex	-	-	-	NA	-	-	-	-
Valent product (V-10208)	-	-	-	NA	-	-	-	-
Resistant cultivars	-	-	-	-	-	NA	-	-

[1] Disease abbreviations: BB = bacterial blight, SR = soft rot, CR = crater rot, DO = damping-off, FB = foliar leaf blights (early & late blight), FY = fusarium yellows, WM = white or pink mold, AN = Anthracnose (*Colletotrichum spp.*).

[2] Efficacy rating symbols: E = excellent (98-100% control), VG= very good (90-98% control), G = good (85-90% control), F = fair (80-85%), P = poor (<80% control), NA = no data available, - = not applicable and/or used, NC = no control – using this management method may increase problems with this pest.

TABLE 9. EFFICACY OF PEST MANAGEMENT TOOLS FOR CONTROL OF WEEDS ON CELERY IN MICHIGAN

Management tool	Annual weeds		Perennial weeds	
	broadleaf	grass	broadleaf	grass
Pre-Plant				
glyphosate (Round-up)	[1]VG	VG	VG	VG
Pre-Emergence				
flumioxazin (Chateau WDG)	VG	VG	P	P
metolachlor (Dual Magnum)	-	G	-	G
trifluralin (Treflan) [C carcinogen]	G	G	G	G
Pre- & Post-Emergence				
linuron (Lorox DF) [C carcinogen]	E*	E**	E*	E**
prometryn (Caparol 4L)	E	E**	E	E**
Post-Emergence				
clethodim (Select, Volunteer)	-	E	-	E***
sethoxydim (Poast)	-	G	-	G***
Other Pest Management Practices				
cover crops	NA	NA	NA	NA
wind breaks	NA	NA	NA	NA
crop rotation	NA	NA	NA	NA
fall tillage (in conjunction with herbicide treatment)	NA	NA	NA	NA
hand weeding	NA	NA	NA	NA
herbicide rotation to reduce resistance	NA	NA	NA	NA
Pipeline pest management tools				

Management tool	Annual weeds		Perennial weeds	
	broadleaf	grass	broadleaf	grass
Prowl H_2O	NA	NA	NA	NA
Spartan	NA	NA	NA	NA
Zidua	NA	NA	NA	NA
Goal Tender	NA	NA	NA	NA

[1] Efficacy rating symbols: E = excellent (98-100% control), VG= very good (90-98% control), G = good (85-90% control), F = fair (80-85%), P = poor (<80% control), NA = no data available, - = not applicable and/or used, NC = no control – using this management method may increase problems with this pest.

* No control over composites, wild carrot and nutsedge. **Effective on only some grasses. *** Weak on quack grass and no nutsedge control.

TABLE 10. TOXICITY OF PESTICIDE ACTIVE INGREDIENTS TO BENEFICIALS

Active ingredient	Amphibians	Aquatic Organisms	Aquatic Invertebrates	Bees	Birds	Crustaceans	Fish	Green Lacewing	Insects	Nontarget Lepidoptera	Mammals	Metasciulus occidentalis	Oyster	Other Plants	Shrimp	Solano Grass	Vascular Plants	Wild Rice	Wildlife	Avoid Water Sources	Ground Water Caution	Restricted Use Pesticide
INSECTICIDES																						
abamectin	r	r	-	y	-	r	y	-	r	-	y	-	-	-	-	-	-	-	-	y	-	-
acephate	-	-	-	y	y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
acetamiprid	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	y	-	-
Bacillus thuringiensis	-	-	-	-	-	-	-	y	-	y	-	y	-	-	-	-	-	-	-	y	-	-
beta-cyfluthrin	-	-	y	y	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
carbaryl	-	-	y	y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
chlorantraniliprole	-	-	y	-	-	-	-	-	-	-	-	-	y	-	y	-	-	-	-	y	y	-
clothianidin	-	y	y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
cyromazine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	y	-
dimethoate	-	-	y	y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	y	y	-
dinotefuran	-	-	-	y	-	-	-	-	-	-	-	-	-	-	y	-	-	-	-	y	y	-
emamectin benzoate	-	-	y	y	y	-	y	-	-	-	y	-	-	-	-	-	-	-	-	y	-	-
endosulfan	-	-	y	y	y	-	y	-	-	-	y	-	-	-	-	-	-	-	-	y	-	y
flonicamid	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
flubendiamide	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
flubendiamide/ buprofezin	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
imidacloprid	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	y	-
indoxacarb	-	-	y	y	y	-	y	-	-	-	y	-	-	-	-	-	-	-	-	y	-	-
malathion	y	-	y	y	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
methomyl	-	-	y	y	-	-	y	-	-	-	y	-	-	-	-	-	-	-	-	y	y	y
methoxyfenozide	-	r	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
neem oil	-	-	y	y	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
oxamyl	-	y	y	y	y	-	y	-	-	-	y	-	-	-	-	-	-	-	-	y	y	y
permethrin	-	y	y	y	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	y
pymetrozine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
pyrethrin/piperonyl butoxide	-	-	-	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
pyrethrin/rotenone	-	-	-	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
spinetoram	-	-	y	y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
spinosad	-	-	y	y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
spirotetramat	-	-	y	r	-	-	-	-	-	-	-	-	y	-	-	-	-	-	-	y	y	-
tebufenozide	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	-

Active ingredient	Amphibians	Aquatic Organisms	Aquatic Invertebrates	Bees	Birds	Crustaceans	Fish	Green Lacewing	Insects	Nontarget Lepidoptera	Mammals	Metasciulus occidentalis	Oyster	Other Plants	Shrimp	Solano Grass	Vascular Plants	Wild Rice	Wildlife	Avoid Water Sources	Ground Water Caution	Restricted Use Pesticide
thiamethoxam	-	-	y	y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	y	y	-
thiamethoxam/ chlorantraniliprole	-	-	y	y	-	-	-	-	-	-	-	-	y	-	y	-	-	-	y	y	y	-
zeta-cypermethrin (2S)	-	-	y	y	-	-	y	-	-	-	-	-	y	-	y	-	-	-	-	y	-	y
NEMATICIDES																						
1,3 dichloropropene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	y	y
metam	-	-	-	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
oxamyl	-	y	y	y	y	-	y	-	-	-	y	-	-	-	-	-	-	-	-	y	y	y
MITICIDES AND MOLLUSCICIDES																						
abamectin	r	r	-	y	-	r	y	-	r	-	y	-	-	-	-	-	-	-	-	y	-	-
dimethoate	-	-	y	y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	y	y	-
malathion	y	-	y	y	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
metaldehyde	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
neem oil	-	-	y	y	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
FUNGICIDES																						
azoxystrobin	-	-	y	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	y	-
azoxystrobin/ chlorothalonil	-	-	y	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	y	y	y	-
azoxystrobin/ propiconazole	-	-	y	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	y	-
chlorothalonil	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	y	y	-
copper ammonium carbonate	-	y	-	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
copper hydroxide	-	y	-	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
copper oxychloride/ copper sulfate	-	y	-	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
copper sulfate	-	y	-	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
cyprodinil/ fludioxonil	-	y	-	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	y	-
DCNA	-	-	-	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
fenamidone	-	-	y	-	-	-	y	-	-	-	-	-	y	-	y	-	-	-	-	y	-	-
mefenoxam	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	y	-
neem oil	-	-	y	y	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
potassium phosphite/ chlorothalonil	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	y	-	-
propiconazole	-	-	-	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
pyraclostrobin	-	-	y	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-

Active ingredient	Amphibians	Aquatic Organisms	Aquatic Invertebrates	Bees	Birds	Crustaceans	Fish	Green Lacewing	Insects	Nontarget Lepidoptera	Mammals	Metasciulus occidentalis	Oyster	Other Plants	Shrimp	Solano Grass	Vascular Plants	Wild Rice	Wildlife	Avoid Water Sources	Ground Water Caution	Restricted Use Pesticide
trifloxystrobin	-	-	y	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	y	-
HERBICIDES																						
clethodim	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	-	y	-	y	-	-
flumioxazin	-	-	y	-	-	-	-	-	-	-	-	-	-	y	-	-	-	-	-	y	-	-
glyphosate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
linuron	-	-	y	-	-	-	y	-	-	-	-	-	-	-	-	-	-	-	-	y	y	-
metolachlor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	y	-
prometryn	-	r	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-
sethoxydim	-	y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	-	-	y	-	-
trifluralin	-	-	y	-	-	-	y	-	-	-	-	-	y	-	y	-	-	-	-	y	-	-

Symbol meanings: y = the label for this substance indicates it is toxic for this group of organisms. r = the label for this substance indicates there is a potential risk of toxicity for this group of organisms.

TABLE 11. TIMELINE FOR CELERY CROP STAGES AND WORKER ACTIVITIES IN MICHIGAN

Worker Activities	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Site Selection, Soil Sampling, Soil Survey																								
Soil Preparation																								
Fertilization																								
Herbicide Application																								
Insecticide Application																								
Fungicide Application																								
Greenhouse																								
Transplant in field																								
Harvest																								
Cover Crops																								
Weeding/Mechanical cultivation																								

TABLE 12. GENERAL TIMELINE FOR CELERY PESTS IN MICHIGAN

INSECTS	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Aphids												
Aster leafhopper												
Carrot Weevil												
Cutworms												
Celery leaftier												
Loopers												
Tarnished plant bug												
Vegetable Leaf Miner												
Wireworms												
Armyworms												
NEMATODES	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northern root-knot nematode												
Pin nematode												
Needle nematode												
Root lesion nematode												
OTHER INVERTEBRATES	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Slugs												
Spider mites												
PATHOGENS	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bacterial blight												
Soft rot												
Crater rot												
Damping off (Greenhouse)												
Fusarium yellows												
White or pink mold												
Rusts												
Cercospera leaf spot												
Septoria leaf spot												
Anthracnose												
WEEDS	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Annual Broadleaf												
Annual Grass												
Perennial Broadleaf												
Perennial Grass												
Yellow nutsedge												

ACKNOWLEDGEMENTS

There are several people who I would like to thank for their help in facilitating the workshop to rework the previous PMSP document for celery in Michigan. Brian Cortright (Research Assistant; Department of Plant Pathology, MSU) coordinated and led part of the workshop and also provided assistance in the rewriting of this document. Bill Steenwyck (Extension Educator, MSU) secured a facility to host the workshop and also organized celery growers and stakeholders for the workshop. Tim Riley (Technical Sales Representative, Wilbur-Ellis Company) catered the lunch of the workshop. Jarrod Morrice (Student worker; Department of Plant Pathology, MSU) helped to re-write and reformat the original document to produce the new PMSP document. Sheila Linderman (Research Assistant; Department of Plant Pathology, MSU) also helped to revise the document in its early stages of development.

REFERENCES

1. Anonymous (2010) Vegetables Annual Summary, 01.27.2010, USDA NASS Publications. Online.
2. Zandstra BH, Dudek TA, Grafius EJ, Lacy ML, Warncke DD (1986) Commercial Vegetable Recommendations: Celery. Extension, Michigan State University, Report
3. Hausbeck M, Cortright B, Rodriguez-Salamanca L (2010). Celery disease control research update. In: *Great Lakes Fruit, Vegetable, and Farm Market Expo* 4-6. Grand Rapids, MI.
4. Kucharek T, Berger D (2000) Early,Late, and Bacterial Blights of Celery. Florida Cooperative Extension Service, Report PP-8.
5. Koike ST, Gladders P, Paulus AO (2007) *Vegetable Diseases: A Color Handbook.* Manson Publishing Ltd, London.