Crop Profile for Celery in Michigan

Prepared: August, 1999

General Production Information

- Michigan celery production yields approximately $14678 annually (based on a five-year average).
- About 2,700 acres are planted annually, with 2,440 harvested (based on a five-year average).(6)
- The average yield of packed, full-sized celery in Michigan is 23 tons per acre (760 60-lb boxes).
- Production *may* exceed 40 tons per acre (1,330 60-lb boxes).
- Production for processing may approach 50 tons per acre.
- About 60% of Michigan celery is packed for fresh market as full sized (2 to 6 dozen) stalks in 60-lb crates.
- About 15% of the crop is packed as hearts, using stalks that are too small for regular pack.
- 25% of Michigan celery is processed for frozen food, soup, juice, or other products.
- Michigan is ranked second in the nation for celery production, with 6.3% of the national commodity. (First-ranked is California)
- Celery production in Michigan has steadily declined from 2,500 to 2,200 acres harvested annually since 1996.(14)(7)

	Celery Production in Michigan
Michigan Ranking	2
Percent of U.S. Production	6.3
Area Planted (5 year average) (a	2,620
Area Harvested (5 year avg.) (ac	2,440
Value of Production (thousands) (5 year average) ($)	14,678

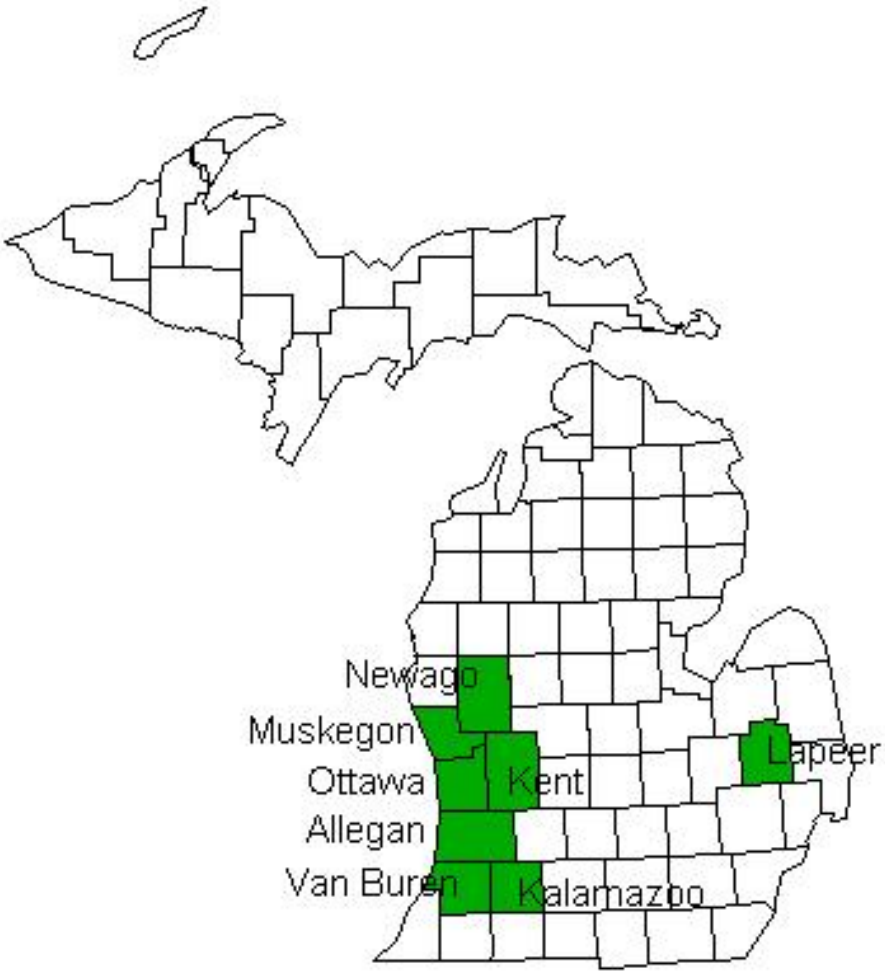
(10)

Production regions

- Michigan's West Central region: Muskegon and Newaygo (380 acres planted)
- Southwest region: Allegan, Kalamazoo, Kent, Ottawa, Van Buren (1,750 acres planted)
- South Central region (160 acres planted)
- Southeast region: Lapeer (270 acres planted)
- Other districts (140 acres planted) (7)

	Counties	Acres Planted	Yield (lb/acre)		Production	
			Fresh	Proc.	Fresh	Proc.
Fresh Market Celery (from 1995-96 MASS, MRS statistics)	**Muskegon**	190				
	Newaygo	190				
	West Central	**380**		**60,000**		**18,000**
	Allegan	320				
	Kalamazoo	300				
	Kent	320				
	Ottowa	430				
	Van Buren	380				
	Southwest	**1,750**	**39,000**	**46,000**	**52,700**	**11,500**
	South Central	**160**		**50,000**		**7,500**
	Lapeer	270				
	Southeast	**270**				
	All other Districts	**140**	**34,000**		**15,300**	
State Totals:		**2700**	**38,000**	**53,000**	**68,000**	**37,000**

(6) (10)



Cultural Practices

All Michigan celery is established from transplants. Because of the high cost of production, a complete stand of uniform, perfectly spaced plants is needed to obtain maximum yields. Celery is a cool season crop that produces highest yields and best quality at temperatures of 60° to 80° F. Young and mature plants can withstand light frosts, but prolonged frosts at temperatures below 28° F will cause damage. Celery is also a shallow-rooted crop; most roots are in the upper 18 inches of soil. It is therefore very susceptible to drought, requiring about 1 to 2 inches of water per week throughout the growing season, and should only be grown where irrigation is available. Good seedling production is an essential first step in celery production.

Spores of two common leaf blights of celery (*Cercospora* and *Septoria*) are carried on the seed. The fungal spores die within about 2 years, so disease incidence can be reduced by storing seeds for three years before planting. If 3-year-old seed is not available, hot water treatment will also help to prevent foliar blights. Celery seed is sown in the greenhouse starting February 1 for transplanting in the field after April 1. After April 20, seedbeds can be established in the field. The last seed is normally planted about June 1 for transplanting in mid-July.

The seed industry is utilizing several techniques to improve the quality of celery seed and to improve the uniformity of germination. One technique is to produce seed in the greenhouse to avoid contamination by fungal blights. The seed is harvested by hand as it matures, to obtain seed that is at a very uniform stage of maturity. The seed is then carefully sized to achieve an additional degree of uniformity.

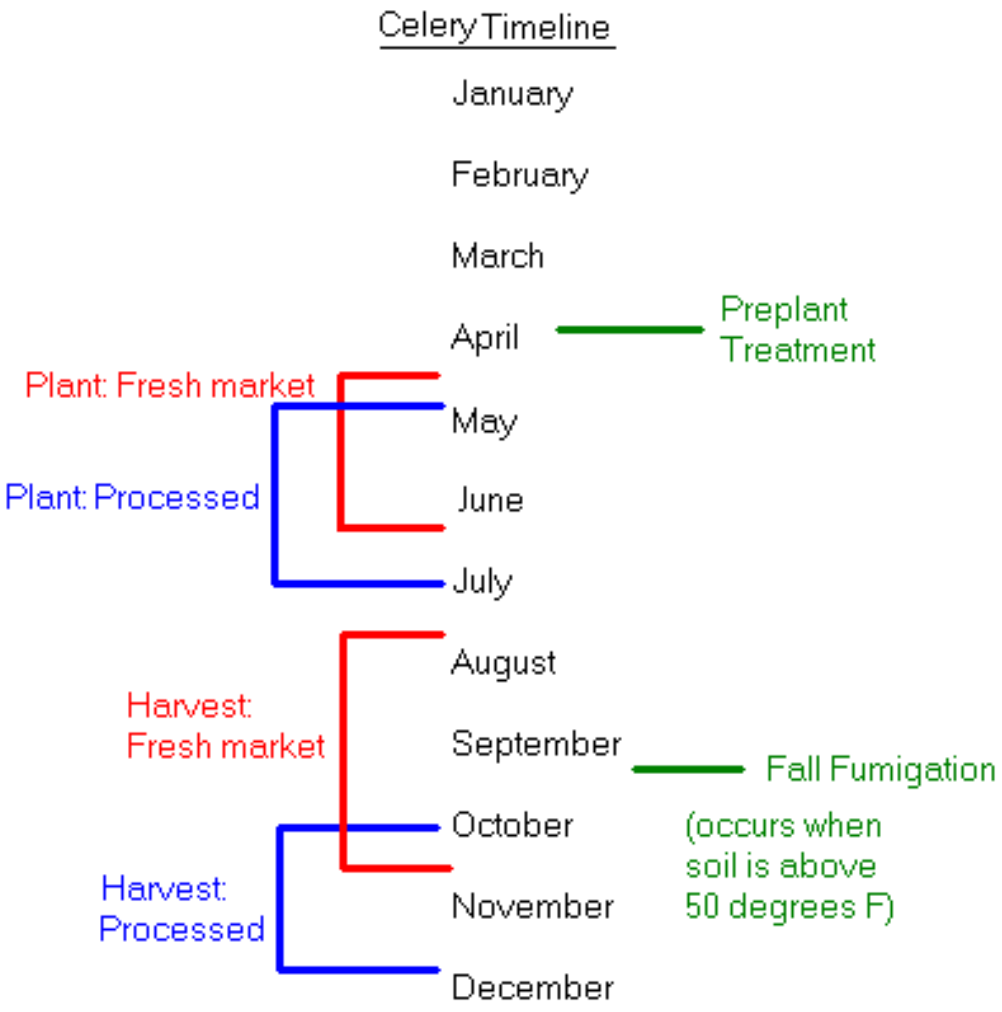
The soil in transplant beds is fumigated in the fall, when soil temperatures are above 50° F, to kill insects, nematodes, disease organisms and weeds. Seedbed soil should be tested each year for soluble salts, pH, and nutrients with a greenhouse soil test, which gives recommendations specifically for transplant production. Many production problems are caused by high or low soil pH, or high soluble salts in the soil. These conditions can be checked regularly by growers with a pH meter and conductivity meter.

Celery should be rotated with other crops whenever possible to avoid a buildup of pests in the soil. Onions or potatoes are good rotation crops with few pests in common with celery. Corn or sudangrass should be included in the rotation every five years. A winter cover crop of barley or rye will reduce wind erosion and add active organic matter to the soil.

Standards for Celery Production in Michigan

The grade standards for Michigan Seal of Quality are equal to or better than U.S. Extra No. 1. To meet the standard, stalks must be fairly well developed and well formed, have good heart formation and a uniform green color; they must be fresh and crisp, well trimmed, compact, and clean. The average midrib length of the outer petioles must be at least 8 inches between the butt and the first node. The stalks must be no more than 1.5 inches shorter than the width of the container (the direction the celery lies from butt to tip). Container width must be given in whole, even numbers, such as 14 or 16 inches. Full size boxes must average 65 lb gross weight and 58 lb net weight when packed. **The stalks must be free from blackheart, brown stem, soft rot, pink rot, and other diseases**. There can be no damage from freezing, growth cracks, horizontal cracks, pith, seedstems, or suckers.

(14)

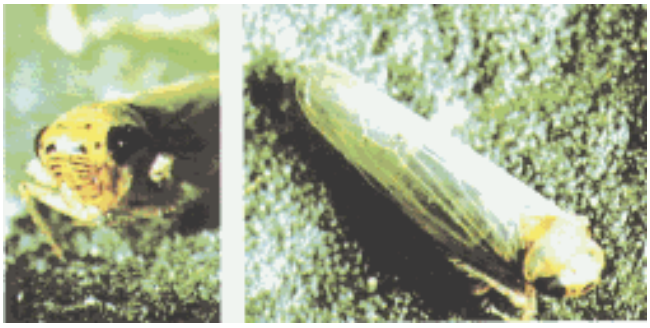


Chemical Controls: Critical Use Issues

- No information available

Insect Pests

Aster Leafhopper



Biology

The aster leafhopper (*Macrosteles fascifrons*) is a key pest of celery, as well as many other vegetable crops. The aster leafhopper does not seriously damage celery; however, it transmits a phytoplasma that causes aster yellows. The adult and nymph aster leafhoppers have piercing mouthparts that they use to enter into vascular tissues of plants to extract sap. When they penetrate the tissue, they release pathogen-transmitting saliva. Aster yellow diseases dwarf the celery, causing it to be abnormally shaped and have poor flavor, often reduces the size leading to losses in both quality and quantity of celery yields. The phytoplasma also pre-disposes plants to other diseases such as soft rot.(3)

Control of aster yellow disease in Michigan is dependent on controlling the population of aster leafhoppers. Both overwintering and migratory aster leafhoppers have become key pests, but the migratory leafhoppers are considered to be less of a problem than the local population.

The migratory population is dependent on conditions in the southern states (mainly Missouri and Arkansas) where it overwinters. When these states have cold winters, the population decreases. They first arrive in Michigan with warm southerly winds, allowing temperature and wind patterns to be used to predict levels of migratory leafhoppers.(3)

The local population begins migrating to celery fields in late May or early June from overwintering hosts such as small grain, grasses and broadleaf weeds (wild carrot, marestail, and pineappleweed). The aster yellow organism is taken up by the leafhopper during feeding. The disease organism must incubate for approximately three weeks inside the leafhopper before it can be transmitted to other plants. If celery fields are checked 1 to 2 times per week, especially when plants are young, leafhoppers can be treated and prevented. Treatment should be terminated two weeks before harvest, since the disease requires at least two weeks to cause symptoms in the celery.

Cultural Controls

Removal of infected plants.

Weed control is an essential part of controlling aster leafhopper. Removing weeds and winter grasses near celery fields can decrease the local population significantly. Linuron (Lorox) has been used for weed control; however, some resistance is developing.(3)

Early seeding helps the crop to mature before the disease becomes well established. Because fresh market growers use early-harvest varieties of celery while processed celery is a late-harvest variety, processed celery gets significantly more exposure to the disease than does fresh market celery.

Cultural Controls
No information available

Chemical Controls

Acephate
Azinphos-methyl
Permethrin

Alternative Controls
No information available

Carrot Weevil

Biology
Carrot weevil (*Listronotus oregonensis*) infestation has caused serious economic damage to celery producers in Michigan. Initial damage is evidenced by small circular feeding holes left by adult insects on the underside of leaf petioles. Later damage will appear as larval tunneling on the outer surface of the celery root, rendering the crop unacceptable for fresh or processing markets. Early season damage usually occurs to plants in border rows or row ends, near field margins.

Adult weevils overwinter in fields, field margins, and ditchbanks in the upper 2-3" of soil, before emerging in mid-April to late May to begin feeding and egg laying on the petioles or crown of the celery. Larvae usually hatch within a week and bore down to the roots. There they spend two to four weeks feeding and maturing before leaving to pupate in the surrounding soil. Adults emerge from these pupae as early as mid-June, and begin laying eggs within two weeks. Since a female may continue to lay eggs until mid-late August, all stages of development may be present at any one time. Monitoring for carrot weevils should be done in spring and early summer, before damage has become serious.(4)

Cultural Controls
Sound cultural practices to minimize spread of infestations, and

Carefully timed foliar sprays for adults or larvae, where needed.

In fields that consistently have problems, the most economical solution may be to rotate to a crop other than carrots or celery and maintain good control of weed hosts for one or two years until the infestation has been reduced or eliminated. Because the adults rarely fly, rotation can also be a very *effective* means of control. For rotation to be effective, there must be a barrier, such as a water-filled ditch or a road between the fields, and good control of the weevil's weed hosts. One year of rotation to a non-host crop with proper weed control and field separation will give effective control of weevils for several years. Late planting (e.g. mid-June) will also reduce damage.(14)

To prevent spread of the infestation, properly dispose of culls and trimmings from infested fields. Also, extra care should be taken to prevent infestation on greenhouses or seedbeds where carrot weevils may multiply and be spread throughout the fields with the transplants. Pull any dead or dying plants and examine the roots and surrounding soil for larvae or pupae. This is especially important in greenhouses and seedbeds. Proper soil sterilization will greatly minimize problems in the greenhouse.

Chemical Controls
Because the adults are very hard-bodies and do little feeding, and the eggs and larvae are inside the plant, foliar insecticides provide limited control. Careful scouting and precise timing of insecticide treatment will improve control. For example, insecticides for adult control should be applied after the adults become active in the spring, but before they begin egg-laying. Insecticides for larval control should be applied after egg laying has begun, but before serious damage has occurred.(14)

Some common sprays used to control carrot weevils are:
Oxamyl
Azinphos methyl
Permethrin

Alternatives Controls
No information available

Tarnished plant bug

Biology
Tarnished plant bug (*Lygus lineolaris*) adults occasionally cause serious damage in celery. They are ¼ to 3/8 inches long, brown to green, with backs shaped like a shield. They attack young leaves in the heart of the plant, sucking plant juices and injecting toxic saliva. Initial damage appears as small, reddish brown spots on the young petioles. The young leaves die and soft rot sets in. Tarnished plant bugs feed and reproduce on many crops and weeds and move into and out of fields rapidly.(3)

Fields should be checked regularly and application of insecticides begun as soon as plant injury or bugs are evident.

Cultural Controls

No information available

Chemical Controls

Acephate
Azinphos methyl
Carbaryl
Methomyl
Permethrin

Alternative Controls
No information available

Variegated cutworms

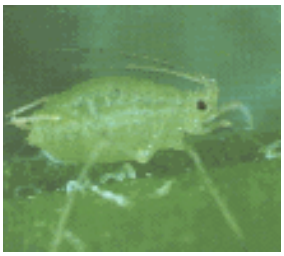
Biology
Variegated cutworms (*Peridroma saucia*) larvae feed on celery stalks and petioles and may be present as a contaminant at harvest. Adults lay eggs on the undersides of the leaves, and the larvae move down into the heart of the plant to feed. Egg-laying in celery begins in mid-to-late June and continues until late July or early August. Sex attractant or black light traps can be used to monitor adult activity. Apply routine protective sprays when plants have marketable petioles and adult moths are flying.(3)

Cultural Controls
No information available

Chemical Controls
Methomyl

Alternative Controls
No information available

Green Peach Aphid



Biology

Green Peach aphids are key pests of celery, but are not generally a big problem in celery because of the effectiveness of common controls. They cause damage by transmitting mosaic viruses through sucking, causing twisting and distortion of the new growth.

Green peach aphids are yellow-green, except for winged adults, which have black markings on their bodies. They may overwinter as eggs on an overwintering host or in greenhouses, or migrate into Michigan from southern locations. On the overwintering host, the eggs hatch in the spring and – after several generations – produce winged aphids. These adults migrate to several different weeds and crops. Winged forms are especially common when the host plant is dying or aphids are becoming crowded.

Aphids have extremely high reproductive rates – each aphid can give birth to 50-100 young, and there may be five to ten generations per year. Usually population numbers are held in check by natural enemies (lady beetles, lacewings, hover fly larvae, lacewing larvae, fungal diseases, and tiny wasps), but insecticide or fungicide sprays sometimes disrupt this natural control and result in aphid outbreaks. Spraying with the wrong insecticide only increases aphid problems by killing natural enemies.

Aphids can be monitored by direct visual observation of plant foliage. Traps can also be used, but identification is difficult because many harmless aphids and other insects may also be trapped. Green peach aphids can rapidly build up resistance to insecticides because females reproduce without mating, and offspring are genetically identical to the mother.

Cultural Controls
Maintain natural enemies' populations.

Chemical Controls

Acephate
Endosulfan
Imadacloprid
Methomyl
Naled
Oxamyl
Azinphos-methyl
Permethrin
Alternatives

Alternatives
No information available

Celery and Cabbage Loopers

Biology

Celery and Cabbage Loopers (*Anagraoha falcifera* and *Trichoplusia ni*) are similar in appearance; small, green worms, 1 inch long with white stripes on their sides that move by humping their back, and forming a 'loop,' from which they get their name. Celery loopers overwinter in Michigan and become active in early May. Cabbage loopers migrate into the state and become a problem in late June and July. The damage appears as holes in the foliage and small pits in the petioles. The larvae generally do only minor damage to celery, but may be serious contaminants of harvested celery, and are difficult to wash off.

When the loopers are mature, they are harder to control. Therefore, fields should be monitored regularly for loopers and other insects. A foliar insecticide should be sprayed when adults or larvae appear… repeating as needed.(3)

Cultural Controls
No information available

Chemical Controls

Methomyl
Acephate
Bt
Endosulfan
Permethrin

Alternative Controls
No information available

Vegetable Leafminers

Biology
Vegetable leafminers can severely injure celery foliage. The larvae tunnel in leaf tissue, causing product contamination and stunted plants if populations are high. Leafminers do not overwinter in Michigan, but may be carried into the state on celery transplants or trimmings, or on other plants, such as chrysanthemums. **They are highly resistant to most insecticides.** The most effective control is to dispose of infested plants and trimmings by deep burying or composting.(3)

Cultural Controls
No information available

Chemical Controls
No information available

Alternative Controls
No information available

Insecticide Profiles

Carbaryl (carbamate)

Formulations: Sevin
Pests Controlled: aster leafhopper
Percent of Crop Treated: used by 22% of Michigan celery farmers on 100% of the acreage. Carbaryl was applied to 14% of acreage in celery production in Michigan; 10% of farmers in the Northwest region, 33% of farmers in the West Central region
Types of Applications: foliar spray
Application Rates: 0.77 pounds per acre
Number of Applications: 2.9 applications annually
Timing: applied as a foliar spray in response to sweep net scouting
Pre-Harvest Interval: 30 days
REI: 12 hours
Use in IPM Programs: no information available
IPM concerns: Kills beneficial insects. Excessive use leads to aphid outbreaks
Use in Resistance Management Programs: Used as part of a resistance management program.
Efficacy Issues: inexpensive yet effective
Advantages: Product can also be used on other crops such as onions. It is an inexpensive yet effective product. At least one processor allows its use.
Disadvantages: At least two processors do not allow the use of Carbaryl on celery, so many growers who do not know where their crop will be marketed do not use the pesticide.
(8)(10)(11)

Malathion (Organophosphate)

Formulations: Cythion
Pests Controlled: is used to control a broad spectrum of insects control including aster leafhopper and aphids
Percent of Crop Treated: Malathion was applied to 15% of the acreage. It is used by approximately 10% of Michigan celery farmers on approximately 100% of the acreage. About 20% of West Central regional farms use Malathion, while only about 1% of Northwest regional farms use the chemical.
Types of Applications: foliar spray
Application Rates: 1.23 pounds per acre
Number of Applications: 3.2 applications annually
Timing: The foliar spray is applied, in the West Central region, at the three or four leaf stage; in the North Central region, at any stage necessary in response to sweep net scouting.
Pre-Harvest Interval: 30 days
REI: 12 hours
Use in IPM Programs: no information available
IPM concerns: This is a broad-spectrum insecticide that kills beneficial insects.

Use in Resistance Management Programs: The product is part of a resistance management program. In the West Central region, growers report that the product is losing its effectiveness. In the Northwest region, growers report a need for Organophosphate or Carbamate insecticides to rotate with synthetic pyrethroids to avert the development of resistance to synthetic pyrethroids.
Efficacy Issues: In West Central region, Malathion has only medium efficacy.
Advantages: Processors accept celery treated with this product.
Disadvantages: expensive
(8)(10)(11)

Methyl parathion (Organophospate)

Formulations: Penncap-M
Pests Controlled: carrot weevils, aster leafhopper, aphids
Percent of Crop Treated: used by approximately 20% of Michigan celery farmers
Types of Applications: spray
Application Rates:(suggested) 3/4 to 1 pt (2)
Number of Applications: repeat as necessary (2)
Timing: sprayed only after the celery has reached the six-leaf stage and only on fields on which weevils have been monitored
Pre-Harvest Interval: 30 days
REI: 48 hours
Use in IPM Programs: no information available
IPM concerns: This is a broad-spectrum insecticide and may also target beneficial insects.
Use in Resistance Management Programs: used as part of a resistance management program in the West Central region
Efficacy Issues: no information available
Advantages: Inexpensive. Encapsulated insecticide has a slower release rate and therefore allows a larger window of opportunity to target adults.
Disadvantages: Toxic to applicator. Risk of honeybee and other non-target loss.
(8)(10)(11)

Oxamyl (Carbamate)

Formulations: Vydate
Pests Controlled: insecticide/nematicide -- carrot weevil, nematodes
Percent of Crop Treated: 10% of acres on 20% of farms
Types of Applications: foliar spray
Application Rates: 2 to 8 lbs Al/acre
Number of Applications: 1 to 3
Timing: based on scouting, soil sample and field history
Pre-Harvest Interval: 14 days
REI: 48 hours
Use in IPM Programs: This is the only nematicide that can be applied after the crop has been planted
Use in Resistance Management Programs: used as part of a resistance management program in the West Central region.

Efficacy Issues: Moderate efficacy
Advantages: Systemic insecticide. Translocates downward when applied as foliar spray. Ease of application because material can be applied at planting time, unlike fumigation. In the Northwest region, it is the only material that is available for control of carrot weevil.
Disadvantages: Growers in the West Center region report that there may be groundwater concern.
Resistance Management Concerns: May become a resistance management issue in the West Central region.
(8)(10)(11)

Esfenvalerate (Synthetic Pyrethroid)

Formulations: Asana, Conquer
Pests Controlled: aster leafhopper, carrot weevils
Percent of Crop Treated: Applied to 18% of the acreage(8)
Types of Applications: foliar treatment(2)
Application Rates: 0.03 pounds per acre(8)
Number of Applications: 2.8 applications annually(8)
Timing: begin in spring (2)
Pre-Harvest Interval: 7 days (2)
REI: 12 hours
Use in IPM Programs: no information available
Use in Resistance Management Programs: is used as part of a resistance management program in the West Central region
Efficacy Issues: High efficacy rate for controlling aster leafhopper
Advantages: In the Northwest region, most growers prefer this product because processors are more likely to allow use of this product
Disadvantages: Kills predators of mites, which could lead to a mite outbreak.
(8)(10)(11)

Methomyl (Carbamate)

Formulations: Lannate SP, Lannate LV
Pests Controlled: Sunflower aphid, Green peach aphid, Tarnished plant bug, Loopers (nonspecific), Corn borer
Cutworm, and Leafminer (nontargeted)
Percent of Crop Treated: 100% acres on 100% farms
Types of Applications: ground, foliar spray
Application Rates: 8 to 20 lbs Al/acre
Number of Applications: 2 to 4 lbs/acre
Timing: Emergence/Re-emergence of cutworms
Pre-Harvest Interval: 7 days
REI: 48 hours
Use in IPM Programs: Lannate is used because it is effective against 2-3 insects at once
Use in Resistance Management Programs: After Lannate is used 1-2 times, growers switch to a chemical that is not an organophosphate or a carbamate.

Efficacy Issues: Moderate efficacy
Advantages: Broad Spectrum will control multiple insects, compatible with other pesticides, rapid knockdown (19)
Disadvantages: toxic to bees, fish and birds (19)
(8)(10)(11)

Endosulfan (Organochlorine)

Formulations: Phaser, Thiodan
Pests Controlled: aster leafhopper, aphids
Percent of Crop Treated: no information available
Types of Applications: foliar spray
Application Rates: (suggested) 3 EC, 1 1/3 to 2 2/3 qt or 50 WP 1 to 2 lb (2)
Number of Applications: Currently limited to one application a year
Timing:apply when insects first appear (19)
Pre-Harvest Interval: 4 days (2)
REI: 24 hours
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: Moderate efficacy
Advantages: compatible with most pesticides, relatively non-toxic to bees (19)
Disadvantages: highly toxic to fish, corrosive to iron (19)
(8)(10)(11)

Acephate

Formulations: Orthene
Pests Controlled: Tarnished plant bug, Aster leafhopper, Sunflower aphid, Green peach aphid, loopers
Percent of Crop Treated: 100% acres on 95% farms
Types of Applications: foliar spray
Application Rates: 1.25-1.33 lbs Al/acre
Number of Applications: 1– 2
Timing: early
Pre-Harvest Interval: 21 to 40 days
REI: 24 hours
Use in IPM Programs: This is one of the only aphid insecticides left for celery
Use in Resistance Management Programs: no information available
Efficacy Issues: good (2)
Advantages: Orthene is used because it is also effective against Aphids. Similar to Lannate (methomyl), Orthene is used for multiple pests.
Disadvantages: Long pre-harvest interval (21 days) so cannot be used on mature celery.
(8)(10)(11)

Azinphos-methyl (Organophosphate)

Formulations: Guthion Solupak 50 WP
Pests Controlled:aster leafhopper with some control over carrot weevil adults (2)
Percent of Crop Treated: no information available
Types of Applications: foliar treatment
Application Rates: 1 lb
Number of Applications: maximum 3 per year (2)
Timing: no information available
Pre-Harvest Interval: 14 days (2)
REI: 48 hours
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: High
Advantages: wide spectrum insecticide
Disadvantages: Ineffective against larvae, only useful for control of adults.(8)(10)(11)

Permethrin (Pyrethroids)

Formulations: Ambush 2 EC, Ambush 25 WP, Pounce 3.2 EC, Pounce 25 WP
Pests Controlled: aster leafhopper, cutworms, loopers
Percent of Crop Treated: no information available
Types of Applications: foliar treatment
Application Rates: (suggested) Ambush 2 EC, 6.4 oz to 12.8 oz; Pounce 3.2 EC 4 to 8 oz; Pounce 25 WP 6.4 to 12.8 oz (2)
Number of Applications: no information available
Timing: no information available
Pre-Harvest Interval: 1 day (2)
REI: 12 hours
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: High
Advantages: Short pre-harvest interval. Works better than Acephate.
Disadvantages: Ineffective against larvae, only useful for control of adults. Can cause increased aphid problems (2)
(8)(10)(11)

Bt's (Bacterials)

Formulations: Dipel, Agree, Biobit, Condor, Cutlass, Javelin, MVP II, Mattch, VAult Xentari
Pests Controlled: loopers
Percent of Crop Treated: no information available
Types of Applications: no information available
Application Rates: no information available
Number of Applications:no information available
Timing: suggested 4 weeks prior to harvest as needed (2)
Pre-Harvest Interval: 0 days (2)

REI: 4 hours
Use in IPM Programs:no information available
Use in Resistance Management Programs:no information available
Efficacy Issues: good (2)
Advantages: good selective treatment (2)
Disadvantages: This is the last measure because the insect must ingest the pesticide during its larval stage.
(8)(10)(11)

Diseases

Aster Yellows

Biology
Aster yellows are caused by a mycoplasma-like organism that causes the celery plant to yellow and dwarf, and to acquire an unpleasant taste. Leaves of infected plants become twisted, stunted, and yellow, and most develop a dense cluster of dwarfed and chlorotic adventitious shoots. This increased lateral rootlet development makes harvesting difficult to impossible, and predisposes roots to diseases. Celery infected at early stages are not likely to survive. Losses of 10-25% are not uncommon.

The mycoplasma for aster yellows overwinters in weeds and is transmitted to plants by aster leafhoppers, a key pest for celery and other commodities in Michigan. The aster leafhopper infects the plant by penetrating the vascular tissues while feeding, and injecting the pathogen through its saliva. Once an aster leafhopper has been infected with the pathogen, it incubates for three weeks before becoming infectious. It takes 24 to 30 days for an infected plant to express symptoms.(1)

Cultural Controls
Weed control is essential in controlling aster yellows. Weed and grass hosts near the target crop can harbor the pathogen – as well as aster leafhopper eggs – over the winter. While some celery varieties are more resistant to the disease than others, none are totally resistant.

Early planting allows plants to become well established prior to possible infection. Removal of infected plants will help to prevent spread of an existing infection, although this is not feasible for commercial production.(1)

Chemical Controls
Chemical control of leafhoppers

Alternative Controls
No information available

Bacterial Blight (*Xanthomonas carotae*)

Biology
Bacterial Blight, caused by the bacteria *Xanthomonas*, is evidenced by yellow-ringed dark spots on leaves and roots first appearing on the lower side of the leaf. Bacteria moves from the lesions into the vascular tissue and on to the stem. Dark streaks may form on the petioles, accompanied by a sticky, yellow exudate. The seed-borne pathogen can survive in plant residue, and is spread by splashing and running water and through soil from wind and implements. Leaves are infected primarily during extended periods of high humidity. Bacterial blight is not a problem in all years.

Cultural Controls
Planting only Xanthomonas-indexed seed to avoid introduction of the disease

Turning under celery residue to hasten decomposition

Avoiding continuous celery crops

Crop rotations are helpful in controlling Bacterial blight on celery. A 2 or 3 year rotation scheme is suggested, although this does not assist with seed-borne pathogens.

Chemical Controls
Copper hydroxide (Kocide 2000) and Champ2 (copper 37.5%) are suggested for use once the bacterial blight appears. The suggested application rate for Kocide (50W) is 2 lb and Champ2 is 2 2/3 pt every seven to ten days after the disease is spotted.(8)

Alternative Controls
No information available

Damping off *(Pythium)*

Biology
Damping off can be a problem. It is a seed disease caused by several fungi, most commonly Pythium, a key cause of pre-emergence and post-emergence damping off. Infection rates can be high, particularly during the periods of cool, wet weather, and can lead to germination failure. Infected seedlings wilt, turn brown, and die, resulting in poor stands. Seedlings that are attacked at the ground level develop a water-soaked, discolored stem and topple over. Infected plants seldom recover. Yield loss due to pythium damping off can be as severe as 100%.(2)

Pythium develops as white mycelium, branching off and forming reproductive structures. The spores move

through water to the host, surviving best on dead plant and animal matter, but able to survive on living plants in particularly wet soils. The fungus enters plant cells, consumes cellular material, and kills the cells. If the initial infection of a plant occurs at a more mature stage of the plant's development, the host is able to resist the fungal growth. However, at more immature stages -- such as seeds and young seedlings -- the fungus is able to grow readily into the plant tissues and kill the plant. Young roots can be attacked by fungus at any stage of plant growth.(2)

Cultural Controls

- Regulation of soil moisture is essential in controlling damping off disease
- Seedlings must not be overwatered – although this is not always in the growers control
- Good drainage is important in limiting disease development
- Planting at times conducive to rapid plant growth minimizes the opportunity for infection
- Compost and other soil amendments are able to improve drainage and air circulation and thereby decrease infection.
- Crop rotation helps to decrease the incidence of damping off.

Chemical Controls
Chemical controls are sometimes recommended for difficult cases:

- Oxadixyl (Anchor) is a commonly used seed treatment. The suggested rate is 1½ lb per 100-lb seeds.
- Thiram is used for seed treatment against a variety of diseases in vegetables, fruit and turf. It is a broad-spectrum pesticide and less expensive than alternatives, Captan and Iprodione. Thiram is used on 15% of the farms (25% of the acres) in the West Central Region. It is used on 75% of the farms (100% or the acres) in the North West Region. In the West Central Region Thiram is used only when a problem is suspected. The suggested rate is 8 oz per 100 lb of seed for seed treatment.
- Iprodione (Rovral) (B2 carcinogen) is the preferred application in the West Central Region of Michigan, with Captan used as a seed treatment.
- Metalaxyl (Ridomil) (B2 carcinogen) is a new product used in the West Central Region. It is usually applied in a 7-inch band among the rows at planting. The suggested rate is Ridomil Gold EC, 1 to 2 pt, and Ridomil Gold WSP, 1 to 2 lb. There are concerns regarding resistance in the use of Metalaxyl.(8)

Alternative Controls
Thiram is less expensive than alternatives, Captan and Iprodione (Rovral). Mefenoxam, oxadixyl, fludioxonil are also alternatives to Thiram.

Fungicide Profiles

Chlorothalonil(Nitrile Compound)

Formulations: Bravo (Bravo 500, Bravo 720, Bravo Ultrex, Bravo Weather Stik), Echo, Daconil
Diseases Controlled: Alternaria Leaf Spot and Cercospora Leaf Spot

Percent of Crop Treated: 59% of the acreage
Types of Applications: foliar
Application Rates: 1.08 pounds per acre
Number of Applications: 4.2 applications annually
Timing: early, suggested 7-14 day intervals (21)
Pre-Harvest Interval: 7 days(2)
REI: 48 hours
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: no information available
Advantages: broad-spectrum foliage protectant fungicide
Disadvantages: B2 carcinogen
(1)(8)(11)

Copper hydroxide

Formulations: Kocide 2000
Diseases Controlled: Alternaria Leaf Spot, Cercospora Leaf Spot and Bacterial Leaf blight
Percent of Crop Treated: 26% of the acreage
Types of Applications: foliar treatment
Application Rates: 0.51 pounds per acre
Number of Applications: 4.1 applications
Timing: begin when disease threatens
Pre-Harvest Interval: 0 days (2)
REI: 24-48 hours (2)
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: no information available
Advantages: no information available
Disadvantages: toxic to fish
(1)(8)(11)

Metalaxyl

Formulations: Ridomil Gold EC, Ridomil Gold WSP, Ridomil Gold GR
Diseases Controlled: Damping off
Percent of Crop Treated: no information available
Types of Applications: broadcast
Application Rates: Ridomil Gold EC 1 to 2 pt, Ridomil Gold WSP 1 to 2 lb, Ridomil Gold GR20 to 40 lb.
Number of Applications:1
Timing: planting treatment
Pre-Harvest Interval: not applicable
REI: 48 hours (2)
Use in IPM Programs: no information available

Use in Resistance Management Programs: no information available
Efficacy Issues: no information available
Advantages: long lasting activity (21)
Disadvantages: B2 carcinogen, resistance concerns, corrosive (21)
(1)(8)(11)

Nematodes

Biology
Nematodes are a serious problem in celery production. Northern root-knot, pin, and root-lesion nematodes attack celery and reduce yields. Growth of affected celery is slow and the size of mature plants is reduced by moderate to high nematode populations. Damage is especially apparent during dry periods or in non-irrigated fields.(2)

It can be difficult to diagnose nematodes because many of the above ground symptoms are similar to a variety of unrelated diseases and abiotic factors. Nematode feeding causes wounds through which microorganisms can enter roots and cause disease. The diagnosis of nematodes requires soil and plant tissue samples and submission to a nematode diagnostic laboratory for analysis.

Key Nematode Pests
The northern root-knot nematode *(Meloidogyne hapla)*, an endoparasite, is a key pest of Michigan celery. They can cause galls and bunching of the roots. The adult female nematode feeds on celery roots and swells, then produces an egg mass at the root surface. The first stage larva develops in the egg, while the second stage larva exits the egg. The second stage larva is worm-like in shape and motile, moving through the soil until it finds a suitable root. The larva then enters the root and becomes sedentary. Nematode juveniles enter plant root tips, migrate through the tissue to feeding sites near the center of the root, and stop movement to feed.

Root lesion nematodes *(Pratylenchus penetrans*) are migratory endoparasites, and are also key pests of celery in Michigan. The nematodes burrow into the cortex of the celery to feed causing necrosis and discoloration, stunting and disfiguration. Root Lesion nematodes repeatedly enter and exit roots, causing tissue damage and making the roots susceptible to secondary pathogens. They overwinter in soil or roots as eggs, while larva and adults are migratory. The eggs hatch in the roots of the plant, or, if root tissue decomposes, are released into the soil. The first larva stage occurs in the egg; the second larval stage is motile and relocates through the soil into the roots. Crop yields are reduced. Seedlings planted in infested soil frequently fail to grow to normal size. Root lesion nematodes have a wide host range.(15)

Needle nematodes are a problem in celery in Michigan.

Pin nematodes have a wide host range including celery. It is a migratory ectoparasite, feeding on mature parts of the root, on epidermal and outer cortical cells. The fourth stage juvenile shows some resistance to

unfavorable environmental conditions. Pin nematodes can causes damage to celery and can also deform carrots. This nematode can occur in very high numbers without apparently causing damage.(17)

Cultural Controls
Proper **sanitation** is helpful in controlling nematodes. The use of clean, uninfected plantings and seeds is important. To avoid infesting new fields, it is important to clean machinery and equipment with water to prevent movement of infested soil and water into fields.(2)

Crop rotations with non-host crops are helpful in controlling some nematodes. Corn, rye, onions and many other crops are resistant to root knot nematodes; rotating with these crops can decrease occurrence of the problem. Rotations can be very successful with cyst nematodes due to their host specificity. **In the West Central Region of Michigan, crop rotation has been highly effective in the control of lesion and root knot nematodes, particularly on muck soils.**(2)

The **planting time** can also help control many nematodes by establishing plants in cooler soil temperatures when nematodes are not yet active. When temperatures are warmer the roots will be established before nematodes cause forking. This is not helpful with the root knot nematode of celery (*meloidogyne hapla*) which is active at lower temperatures. Under hot, dry conditions, summer fallows can help control lesion nematodes. Resistant cultivars are not available.

Chemical Controls
Some recommended chemical controls are:

Soil fumigants (Dichloropropene, and Metham)

Nematicides (such as Oxamyl (Vydate*))

Soil fumigants have been applied in the fall at a depth of 8 inches followed by sealing the soil. **Methyl bromide** has been used as a soil fumigant to control nematodes.

Dichloropropene (1,3-D, Telone II) can be applied as a pre-plant and fall fumigant, it also helps control weeds and diseases. It is injected into the soil a few days before planting to kill nematode eggs. Rates of 26 gal on muck soil, and 15 gal on mineral soil are suggested.

Metham (Busan or Vapam) is a general-purpose fumigant for nematodes, fungicide and herbicide, that can be applied as a fall fumigant or pre-planting fumigant in the spring. While Metham is highly efficient, it is also very expensive.

Oxamyl (Vydate*) is a carbamate used to control nematodes and insects. A systemic insecticide, Vydate is suggested for use as a nematicide as a pre-planting and planting treatment. Oxamyl is used in a variety of formulations in Michigan. Growers generally pre-treat seeds using Oxamyl. The chemical is used primarily by growers on muck soils. In Michigan, 60% of celery farms use Oxamyl on 75% of their acreage. In the West Central Region Oxamyl is used by 100% of the farms. Oxamyl is used when a problem is revealed trough soil tests for nematodes and assessment of the field history. Nematicides are not registered for post planting,

although Oxamyl application for carrot weevil and other insects provides some nematode control. Oxamyl (Vydate*) is the only material available to control carrot weevil in the North West Region.(2)

For pre-planting, broadcast treatment at the rate of 2-4 gal. per 20 gal. of water. The treatment must be incorporated into the topsoil. Vydate can be applied at a rate of 1-2 gal. per 20 gal. of water in the seed furrow during planting.

Vydate is used in the West Central Region of Michigan as part of a rotation program for resistance management, with possible issues in resistance management in the West Central Region, and possible ground water concerns in the North West Region.(2)

Alternative Controls
Some alternative control strategies are:

Nematicidal plants such as Marigolds can decrease nematode levels significantly, although they can be phytotoxic to crops. **Bacterial nematicides** such as Bt can reduce root knot nematodes significantly. **Soil amendments** can be used for nematode control as well; Crab meal and other chitinous materials are nematode suppressing. Organic substances including sewage sludge, certain green manures, sawdust and bonemeal are useful in suppressing nematodes as well.

Reference: (11)

Nematicide Profiles

Dichloropropene

Formulations: 1,3-D, Telone II
Pests Controlled: nematodes
Percent of Crop Treated: no information available
Types of Applications: fumigant
Application Rates: 26 gal on muck soil and 15 gal on mineral soil are suggested
Number of Applications:1
Timing: a pre-plant and fall fumigant; injected into the soil a few days before planting to kill nematode eggs
Pre-Harvest Interval: no information available
REI: 5 days
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: particular effective against cyst forming nematodes and meadow nematodes.(20)
Advantages: also helps control weeds and diseases(20)
Disadvantages: cannot use on heavy soils(20)
(2)(14)(15)

Metham

Formulations: Busan 1020 or Vapam
Pests Controlled: general-purpose fumigant for nematodes, fungicide and herbicide
Percent of Crop Treated: no information available
Types of Applications: fumigant
Application Rates: 75 to 100 gal
Number of Applications: 1
Timing: fall fumigant or pre-planting fumigant in the spring
Pre-Harvest Interval: no information available
REI: 48 hours
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: highly efficient
Advantages: controls bacteria, fungi, weeds and soil insects.(20)
Disadvantages: very expensive
This is the nematicide of choice in Michigan.(18)
(2)(14)(15)

Weeds

Biology
Annual grasses and broadleaf weeds are common weed pests for celery crops in Michigan. Weeds compete with celery for nutrients, sunlight and water, thereupon reducing their size and quality. Serious cases often cause celery to be deformed and unmarketable. Many weeds act as hosts to insects and diseases that may then do further damage. At harvest, weeds cause mechanical problems with machinery.(13)

Weed control is an important aspect of insect and disease control. The aster leafhopper overwinters in weeds and grasses on the edge of fields; removing weeds reduces the population of aster leafhoppers, thus decreasing incidences of aster yellows disease. White mold is a fungal disease of celery that also infects weeds, which can serve as a source inoculum for the celery crop. Pre-emergence as well as post-emergence herbicides are used to control weeds, though some resistance is developing to commonly used herbicides.

Growers can do several things to avoid weed resistance. First, rotate crops often and change cultural practices. Plowing, cultivating, and harvesting earlier or later, will interrupt the life cycle of weeds and help to maintain the genetic diversity. Second, rotate herbicides as much as possible. If two or more herbicides are labeled for a crop, use them alternately whenever possible. Third, use the lowest labeled rate while maintaining good control. There is recent confirmation to common purslane resistance to Lorox and atrazine in Michigan celery fields. As we use fewer, more effective herbicides, the incidence of weed resistance will probably increase. (13)

Cultural Controls
Cultivation is important in removing weeds. When rye or grasses have been planted as windbreaks, the cultivation and removal of these plants also removes many weeds.

Crop rotation is also useful in controlling weeds. Other practices such as mulching and composting can help to reduce the development of weeds as well.(13)

Chemical Controls
Preplant:
Glyphosate
Preemergence:
(Linuron and Trifuluralin) apply after seeding but before celery emerge. Use low rate on light soils, and increase rate on soil containing more clay and organics.
Postemergence:
Emerged broadleaves (Linuron and Metribuzin)
Emerged grasses (Fusilade and Poast)

Alternative Controls
No information available

Herbicide Profiles

Glyphosate (phosphono amino acid)

Formulations: Roundup 4L
Weeds Controlled: emerged perennial weeds
Percent of Crop Treated: No information available
Types of Applications: No information available
Application Rates: Rate of 2-3 pounds AI per acre
Number of Applications: No information available
Timing: apply either prior to planting in the spring or after harvest in the fall
Pre-Harvest Interval: not applicable
REI: 12 hours (13)
Use in IPM Programs: No information available
Use in Resistance Management Programs: No information available
Efficacy Issues: kills most emerged weeds
Advantages: wide spectrum herbicide
Disadvantages: no residual
(8)(11)(13)

Linuron (phenylureas)

Formulations: Lorox 50DF, Linex 50DF
Weeds Controlled: Emerged annual broadleaf weeds and some grasses
Percent of Crop Treated: 74% of the area
Types of Applications: pre- and post-emergence weed treatment Broadcast after celery are 3 inches high
Application Rates: 0.62 pounds per acre
Number of Applications: 1.9 applications
Timing: applied after planting but before emergence
Pre-Harvest Interval: not applicable
REI: 24 hours (13)
Use in IPM Programs: No information available
Use in Resistance Management Programs: No information available
Efficacy Issues: not effective on perennial weeds
Advantages: It is very effective on muck soils
Disadvantages: Some resistance has been reported, some weeds in the *Compositae* family have begun to show resistance to Linuron. Cannot be applied at temperatures above 85° F, at high pressures (above 40 psi) or with other pesticides, it can be harmful to young seedlings
(8)(11)(13)

Trifluralin (Nitroanilines)

Formulations: Treflan 4EC, Trilin 4EC
Weeds Controlled: broadleaves and annual grasses
Percent of Crop Treated: to 4% of the acres
Types of Applications: incorporated into soils
Application Rates: 0.75 pounds per acre
Number of Applications: 1.0 applications
Timing: pre-planting weed control on mineral soils
Pre-Harvest Interval: not applicable
REI: 12 hours (13)
Use in IPM Programs:No information available
Use in Resistance Management Programs: No information available
Efficacy Issues: not very effective on muck soils, very effective, short residual time
Advantages: inexpensive, kills weed seeds as they germinate, rainfall is not required (22)
Disadvantages: can cause phytotoxicity
(8)(11)(13)

Fluazifop-P-butyl (Oxyphenoxy Acid Esters)

Formulations: Fusilade DX 2E
Weeds Controlled: for control of emerged grass
Percent of Crop Treated: 62% of the area
Types of Applications: No information available
Application Rates: 0.11 pounds per acre

Number of Applications: 1.3 applications
Timing: Apply to actively growing grasses
Pre-Harvest Interval: 45 day
REI: 12 hours (13)
Use in IPM Programs: No information available
Use in Resistance Management Programs: No information available
Efficacy Issues:use a high rate on quackgrass (22)
Advantages: broadleaf crops are tolerant (22)
Disadvantages: do not apply more than 6 pt/acre/year
(8)(11)(13)

Sethoxydim (Cyclohexenone)

Formulations: Poast 1.5E
Weeds Controlled: post-emergence control of grasses
Percent of Crop Treated: no information available
Types of Applications: no information available
Application Rates: 0.19 to 0.28 lb AI/ac
Number of Applications: no information available
Timing: Apply to actively growing grasses
Pre-Harvest Interval: 30 days (13)
REI: 12 hours (13)
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues:not effective at temperatures below 60° F(19)
Advantages: selective for emerged grasses (22)
Disadvantages: 5 pt maximum total per acre
(8)(11)(13)

Metribuzin (triazine)

Formulations: Lexone 75DF, Sencor 75DF
Weeds Controlled: controls a wide spectrum of weeds
Percent of Crop Treated: No information available
Types of Applications: broadcast when celery have 5-6 leaves
Application Rates: 0.25 lb AI/ac
Number of Applications: No information available
Timing: broadcast when celery have 5-6 leaves
Pre-Harvest Interval: 60 days (13)
REI: 12 hours (13)
Use in IPM Programs: No information available
Use in Resistance Management Programs: No information available
Efficacy Issues: good
Advantages:control lasts 3-4 months (22)
Disadvantages: Do not apply during cool cloudy weather, or when the temperature is above 85° F (22)

(8)(11)(13)

Metolachlor (acetamide)

Formulations: Dual 8E
Weeds Controlled: germinating grasses, yellow nutsedge
Percent of Crop Treated: No information available
Types of Applications: No information available
Application Rates: 1.5-3 lb AI/ac (13)
Number of Applications: No information available
Timing: Apply before or immediately after transplanting
Pre-Harvest Interval: No information available
REI: 12 hours (13)
Use in IPM Programs: No information available
Use in Resistance Management Programs: No information available
Efficacy Issues: No information available
Advantages: No information available
Disadvantages: need to use high rate on muck soils
Comment: for use in Michigan only by members of Michigan Vegetable Council. (13)
(8)(11)(13)

Prometryn (triazine)

Formulations:Caparol 4L, Cottonpro 4L
Weeds Controlled: germinating or emerged annuals
Percent of Crop Treated: No information available
Types of Applications: broadcast when celery have 5-6 leaves
Application Rates: 1-2 lb AI/ac(13)
Number of Applications: 1
Timing: 2-6 weeks after transplanting but before seeds are 2 inches tall
Pre-Harvest Interval: not applicable
REI: 12 hours (13)
Use in IPM Programs: No information available
Use in Resistance Management Programs: No information available
Efficacy Issues: No information available
Advantages: No information available
Disadvantages: No information available
(8)(11)(13)

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