Crop Profile for Brussels Sprouts in Michigan

Prepared: August, 1999

General Production Information

- Brussels sprouts are sensitive to temperature
- Most areas in Michigan are not suitable to Brussels sprouts production due to the hot summer temperatures
- Michigan has minor production of Brussels sprouts
- California is the top state in Brussels sprouts production

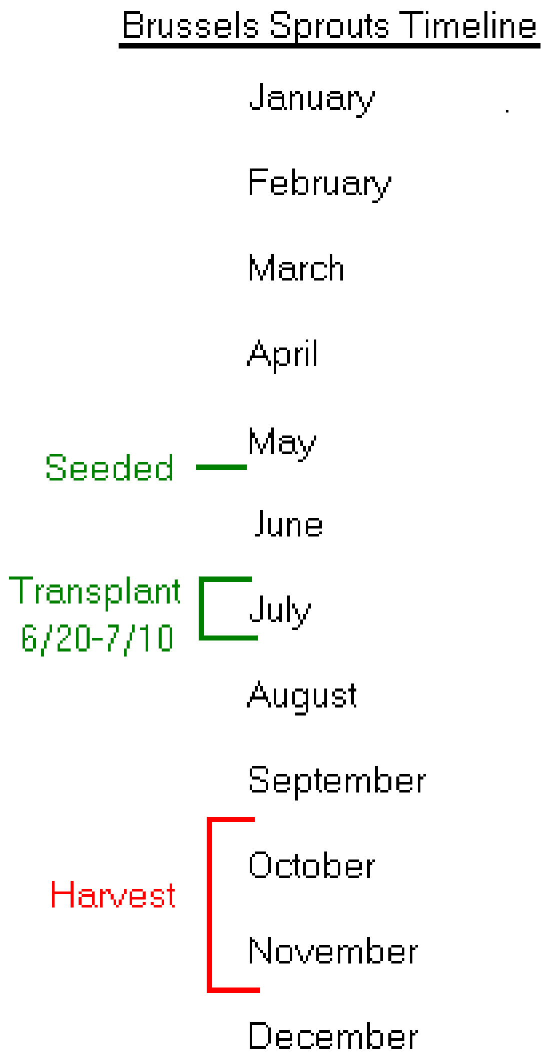
Cultural Practices

Brussels sprouts are a cole crop. The plant produces a stalk with buds at the base of each leaf that are small and cabbage like. These buds, or sprouts, mature from the base of the plant upward. They are harvested when they are 1 to 2 inches in diameter.

Brussels sprouts are a cool-season crop and grow best when daytime temperatures average about 65 ° F or less. Brussels sprouts grow best in Michigan when planted in mid summer for fall harvest. The best quality Brussels sprouts are produced in sunny weather conditions, but high temperatures (over 65° F) result in poor quality produce. Crop rotation and pH control are two important factors in improving production.

Cole crops require 1-2 acre inches of water per week, depending on the size and developmental stage of the plant and the soil type. Cole crops are also sensitive to soil moisture. It is important to grow these crops on well-drained soil. Brussels sprouts grow best on light to medium soils high in organic matter and nitrogen, with pH values between 6.0 and 6.8.

Brussels sprouts are grown from seeds in greenhouses and transplanted (6/20 – 7/10) into fields. Transplants are ready in 5 to 6 weeks. Brussels sprouts mature in 90 to 120 days after transplanting. Brussels sprouts can be picked several times during the growing season, or the entire stalk can be harvested at once. They can be hand harvested or machine harvested September through November. (18) (19)



Because of potential disease problems, crop rotations that do not include members of the *Brassicaceae* family more than 1 year in 3 are more effective. Brussels sprouts are a long season crop, so weeds can be a problem late in the season. Eliminating weeds in the *Brassicaceae* family, such as wild mustard, yellow rocket, shepherd's purse, and wild radish -- since they serve as hosts for several cole crops diseases -- is effective, but difficult to do. (18) (19)

Chemical Controls: Critical Use Issues

There are no alternatives to fonofos in controlling flea beetles and diamondback moths.

Insect Pests

<u>Cabbage Maggot</u> (Delia brassicae)

Cabbage maggots and damage to roots

Biology

The cabbage maggot is a serious pest in early direct-seeded or transplanted cole crops. Pupae overwinter in the soil. The adult flies emerge from the soil in early May and lay their eggs on cole crop plants and related weeds near the soil surface or in the soil at the base of the plants. The short (1/4 inch), white maggots emerge a few days later and begin to eat and burrow through the soil into the plant stems and roots. The maggots feed for 3 to 4 weeks and then pupate. Adults emerge in 2 to 3 weeks. (21) Young plants that are invaded by maggots usually wilt and die. Maggots can kill or stunt plants. (18)

There are three generations of cabbage maggot each year. The first generation does the most damage because it emerges when transplants and seedlings are small. Later generations do less damage because many are killed by high soil temperatures and the crops are advanced enough to withstand some injury. (18)

Cabbage maggot problems are most serious in cool, wet weather. (18)

Cultural Controls

Cabbage maggots are difficult to scout for. (18)

Chemical Controls

- Seedbed Treatment: Diazinon 14G, 21 lb or 500-AG, 3 qt
- Planting Treatment: Lorsban 15G, 4.6 to 9.2 oz or 4 EC, 1.6 to 2.75 fl oz/1,000 ft of row.
- Soil Treatment: Diazinon 50 WP, 1 lb or AG 500, ½ to 1 pt/100 gal
- Soil Treatment: Guthion Solupak 50 WP, ¼ to 3/8 lb or 2L, ½ pt in 50 gallons of water. (2)

Alternative Controls
Several species of parasitic wasps and predators help reduce maggot populations but do not offer complete control (21)

Imported cabbageworm (***Pieris rapae***)

Biology
Imported cabbageworms are the most common foliage pest of cole crops in Michigan. Imported cabbageworm adults, the white butterflies often seen around cruciferous crops, overwinter as pupae and emerge in late April or early May and lay their yellow eggs singly on the leaves of cole crops and other cruciferous crops and weeds. The velvety green worms, which grow to over one inch in length, eat holes in leaves and leave large amount of green debris on the leaves. They tend to leave the plant to pupate in the soil. There are several generations a year, commonly 3, and the adults and larvae may be active until frost. (18)

Damage from imported cabbageworms causes a loss in quality and yield. Fields should be monitored for adult activity and plants should be checked for eggs and larvae. (18)

Cultural Controls
Early planting (21)

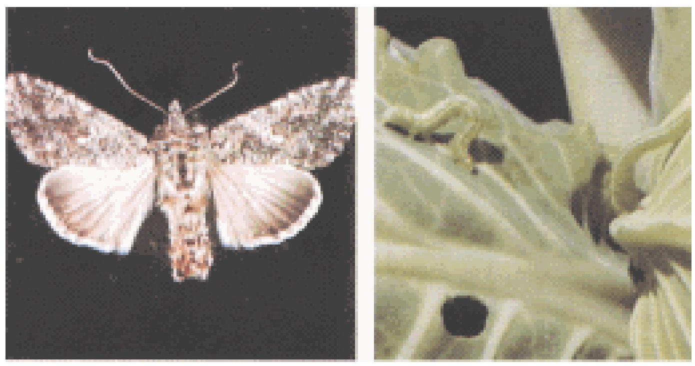
Chemical Controls avoid the use of broad-spectrum insecticides early in the season

- Ammo 2 EC, 2 ½ to 5 oz or WSB, 1 to 2 bags (1 day)
- *Bacillus thuringiensis* Agree, Biobit, Condor, Cutlass, Dipel, Javelin, MVP II, Mattch, Vault or Xentari (0 days)
- Carbaryl (Seven) 80 S, 1 1/2 lb or XLR Plus, 1 to 2 qt (3 days)
- Diazinon 4 EC 1 pt or 50 WP, 1 lb (7 days)
- Dibrom 8 EC, 1 pt (1 day)
- Endosulfan (Phaser, Thiodan) 3 EC, 2 pt or 50 WP, 1 ½ lb (14 days)
- Guthion Solupak 50 WP, 1 to 1 ½ lb or 2 L, 2 to 3 pt (7 days)
- Lannate SP, 1/2 lb or LV, 1 1/2pt (3 days)
- Lorsban 4 E, 1 pt or 50 W, 2 lb (21 days)
- Malathion 57 EC, 2 pt (7 days)

- Orthene 75S 1 1/3 lb (14 days)
- Pyrethrin
  Ambush 2 EC, 3.2 to 6.4 oz or 25 WP, 3.2 to 6.4 oz (1 day)
  Pounce 3.2 EC, 2 to 4 oz or 25 WP, 3.2 to 6.4 oz (1 day)
- SpinTor 2SC, 3 to 6 oz (1 day) (2)

Alternative Controls
Several natural enemies attack imported cabbageworms. Eliminating unnecessary sprays and using the biological insecticide, *Bacillus thuringiensis*, helps preserve these natural enemies. (5)

Cabbage looper (*Trichoplusia ni*)



Biology
Cabbage looper can be a serious pest of cole crops in Michigan. They do not overwinter in Michigan. Cabbage looper adults migrate into Michigan during July and August. The adults are about 1 to 1¼ inches across, gray-brown, and fly and lay eggs mostly at night. The larvae are light green, with a white stripe on each side, about 1 inch long, and move by humping their back like an inch-worm, from which they get their name "looper." There may be 2 or 3 generations per year. As the larvae grow, they become more difficult to control. They cause foliar injury and can be a contaminant at harvest for cole crops. Plant damage and product contamination are similar to that of imported cabbage worm. (18)

Hosts of the cabbage looper include cole crops, celery, tomatoes and potatoes. Eggs are laid singly on the underside of the foliage. (18)

Monitor fields regularly for eggs, larvae, and damage. Apply insecticides as needed for control. Cabbage loopers are much more tolerant of insecticides than imported cabbage worms. Be sure of your identification and use higher rates or more toxic materials on loopers. (18)

Cultural Controls
Early planting is slightly effective in controlling the cabbage looper (21)
Chemical Controls

- Ammo 2EC, 3 3/4 to 5 oz or WSB, 1 to 2 bags (1 day)
- *Bacillus thuringiensis* Agree, Biobit, Condor, Cutlass, Dipel, Javelin, MVP II, Mattch, Vault or Xentari (0 days)
- Dibrom 8 EC, 2 pt (1 day)
- Endosulfan (Phaser, Thiodan) 3 EC, 1 1/3 qt or 50 WP, 2 lb (14 days)
- Guthion Solupak 50 WP, 1 to 1 ½ lb or 2 L, 2 to 3 pt (7 days)
- Lannate SP, 1 lb or LV, 3 pt (3 days)
- Orthene 75 S, 1 1/3 lb (14 days)
- Permethrin
  - Ambush 2 EC, 6.4 oz or 25 WP, 3.2 to 6.4 oz (1 day)
  - Pounce 3.2 EC, 4 oz or 25 WP, 3.2 to 6.4 oz (1 day)
- SpinTor 2SC, 3 to 6 oz (1 day) (2)

Alternative Controls

Loopers can be monitored visually, and adults can be monitored with pheromone (sex attractant) lures and traps. (5)

Diamondback moth *(Plutella maculipennis)*

Biology

Diamondback moth does not do major damage but is often seen in Michigan. The gray adults can overwinter in Michigan on trash in the field, lay eggs in the spring, and the small (1/3 inch) yellow-green larvae emerge soon thereafter. They can also arrive on transplants from the south or migrate into the state. The worms eat numerous small holes in the leaves, they often cause windowpaning. Diamondback moths can cause foliar injury and contaminate the product. Control of diamondback moth is similar to that for other worms. (18) Rainfall can cause natural mortality in diamondback moth larvae, so they are of less concern in wet years. (21)

Cultural Controls

Cover crop mulch or weeds between rows (21)
Overhead sprinkler irrigation (21)

Chemical Controls

- *Bacillus thuringiensis* Agree, Biobit, Condor, Cutlass, Dipel, Javelin, MVP II, Mattch, Vault or Xentari (0 days)
- Carbaryl (Sevin) 80 S, 1 ½ lb or XLR Plus, 1 to 2 qt (3 days)
- Cryolite (Kryocide) 96W, 18 to 16 lb.
- Diazinon 500-AG 1 pt or 50 WP, 1 lb (7 days)
- Dibrom 8 EC, 1 pt (1 day)

- Endosulfan (Phaser, Thiodan) 3 EC, 2 pt or 50 WP, 1 ½ lb (14 days)
- Guthion Solupak 50 WP, 1 to 1 ½ lb or 2 L, 2 to 3 pt (7 days)
- Lannate, ½ to 1 lb or LV, 1½ to 3 pt (3 day)
- Malathion 57 EC, 2 pt (7 days)
- Permethrin
  Ambush 2 EC, 3.2 to 6.4 oz or 25 WP, 3.2 to 6.4 oz (1 day)
  Pounce 3.2 EC, 2 to 4 oz or 25 WP, 3.2 to 6.4 oz (1 day)
- SpinTor 2SC, 1.5 to 3 oz (1 day) (2)

Alternative Controls

Diamondback larvae and pupae can be monitored visually. Adults can be monitored with pheromone (sex attractant) lures and traps. Adults and larvae can be highly resistant to insecticides. A tiny wasp parasitizes diamondback larvae and may kill 70 to 80% of them. Spraying with the wrong insecticides may kill the natural enemies but not control the resistant diamondback moth larvae. *Bacillus thuringiensis* insecticides generally control the diamondback moth larvae and do not kill the wasps. (5)

Thrips (***Thrips tabaci***)

Biology

Thrips are very small (1/16 inch), yellow or brown insects that damage cole crops by rasping the leaf surface and sucking the sap. They cause economic injury primarily on cabbage, where they live and eat inside several layers of leaves. Injury looks like rust spots on the inner leaves. Large areas of leaves can be affected during heavy infestations. Badly infested heads are not usable for fresh market or processing. Thrips damage usually increases during the hot, dry weather of late summer. Once thrips are on Brussels sprouts, it is very difficult to control them. (18)

Cultural Controls

Avoid planting near small grain crops which may act as a source of thrips. (21)

Chemical Controls

Planting treatment:

- Di-Syston 15 G, 7.4 oz/1,000 or 8 E 1.1 fl oz/1,000 ft (30 days) (2)

Thrips are difficult to control with insecticides. (21)

Alternative Controls

Natural enemies are generally not effective in controlling thrips. (21)

Cabbage aphids

Biology
Cabbage aphids are small (1/16 inch), blue-gray insects that suck sap from the plants. They overwinter as eggs on cole crops residue. They are generally most abundant from mid-summer through October. Heavy infestations cause leaves to cup and curl inward. The presence of live or dead ones makes the Brussels sprouts unmarketable. Aphids can be controlled relatively easily with insecticides. (18)

Cultural Controls
Cover crop mulch or weeds between rows decreases populations. (21)
Weeds may provide habitat for natural enemies. (21)
Destroy crop residue after harvest to minimize aphid spread. (21)

Chemical Controls avoid broad-spectrum insecticides early in the season as they may decrease natural enemies and increase aphid populations (21)

- Planting treatment:
  Di-Syston 15 G, 7.4 oz/1,000 or 8 E 1.1 fl oz/1,000 ft (30 days)
- Soil Treatment:
  Admire 2 F, 10-24 oz (21 days)
- Foliar Treatment
  Diazinon 500-AG 1 pt or 50 WP, 1 lb (7 days)
  Dibrom 8 EC, 1 pt (1 day)
  Endosulfan (Phaser, Thiodan) 3 EC, 2 pt or 50 WP, 1 1/2 lb (14 days)
  Malathion 57 EC, 2 pt (7 days)
  Metasystax-R2 SC, 1 ½to 2 pt (10 days)
  Methyl parathion 7.5 EC, ½to 1 pt (21 days)
  Orthene 75 S, 2/3 to 1 1/3 lb (14 days)
  Provado 1.6 R, 3.75 fl oz (7 days). (2)

Alternative Controls
Insecticidal soaps reduce aphid populations without affecting natural enemies. (21)

Insecticide Profiles

Azinphos-methyl (Organophosphate)

Formulations: Guthion Solupak 50 WP
Pests Controlled: cabbage maggot, imported cabbageworm, diamondback moth and flea beetles
Percent of Crop Treated: 50% of the farms, 100% of the acreage
Types of Applications:
Application Rates: 4 lb AI per acre
Number of Applications: In the West Central area it is applied twice during the first one-third of the crop cycle. In the East Central area it is applied 7-10 days after transplanting
Timing: is applied preventatively, because cabbage maggots are hard to scout for
Pre-Harvest Interval: 50 days
REI: 48 hours (2)
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: high
Advantages: wide spectrum insecticide
Disadvantages: Odor can be a problem.
Critical Use Issue: There are no alternative chemicals for flea beetle control

Chlorpyrifos (Organophosphate)

Formulations: Lorsban 50 W
Pests Controlled: imported cabbageworm and cabbage looper, although it also controls cabbage maggots and suppresses flea beetles
Percent of Crop Treated: on 50% of the farms in Michigan, 100% of the acreage
Types of Applications: applied preventatively
Application Rates: 8.4 lb AI per acre
Number of Applications: no information available
Timing: no information available
Pre-Harvest Interval: 50 days (11)
REI: 24 hours (2)
IPM Concerns: Cabbage maggots are difficult to monitor, problem is irreversible. Hazardous to beneficial insects due to broad spectrum.(11)
Use in Resistance Management Programs Fonofos and fumigation are effective alternatives, though fumigation is very expensive.
Efficacy Issues: no information available
Advantages: This is a broad spectrum insecticide
Disadvantages: it is harmful to beneficial insects, recommendation is to treat with

transplant water but this is not the safest method because workers are exposed.(11)

Fonofos (Organophosphate)

Formulations: Dyfonate
Pests Controlled: cabbage maggot, soil insects, cabbage looper
Percent of Crop Treated: 50% of the farms, 100% of the acreage
Types of Applications: It is used preventatively as a soil insecticide
Application Rates: 4 lb AI per acre
Number of Applications:2 applications
Timing: near planting time
Pre-Harvest Interval: 50 days (11)
REI: no information available
IPM Concerns: Broad spectrum, therefore eliminates many beneficial insects.(11)
Use in Resistance Management Programs Very few growers use Fonofos; therefore, resistance is not a likely problem.
Efficacy Issues: no information available
Advantages: broad-spectrum insecticide. Preventative treatment because Cabbage maggot overwinters.(11)
Disadvantages: It is harmful to beneficial insects. More toxic to humans than Lorsban but less toxic than Guthion.(11)
Alternatives: Bt, Premethrin (pyrethroid), and thiodicarb (carbamate) have good efficacy as alternatives to control cabbage looper
Critical Use Issue: There are no alternatives to fonofos in controlling flea beetles and diamondback moths.

Methomyl (Carbamate)

Formulations: Lannate SP, Lannate LV
Pests Controlled: control aphids, imported cabbageworm, cabbage looper, thrips, flea beetles and diamondback moth
Percent of Crop Treated: 100% of the farms, 100% of the acreage
Types of Applications: foliar treatment
Application Rates: 0.5 lb AI per acre
Number of Applications: twice in a growing season
Timing: In the East Central region growers apply the last 4 weeks of the season
Pre-Harvest Interval: 1 day(11)
REI: 48 hours (11)
Use in IPM Programs: It needs to be rotated with other chemicals to avoid the development of resistance.
Use in Resistance Management Programs: It needs to be rotated with other chemicals to avoid the development of resistance.
Efficacy Issues: good efficacy

Advantages: It is a broad-spectrum insecticide
Disadvantages: highly volatile and presents human health concerns, it is harmful to beneficial insects
Alternatives: Bt and Permethrin (pyrethroid) with poor efficacy.

Naled (Organophosphate)

Formulations: Dibrom 8 EC
Pests Controlled: imported cabbageworm, cabbage looper, diamondback moth, thrips and aphids
Percent of Crop Treated: 100% of the farms, 100% of the acreage
Types of Applications: foliar treatment
Application Rates: 4 lb AI per acre
Number of Applications: once in a growing season
Timing: It is used late in the season because it can be used up to 4 hours before harvest
Pre-Harvest Interval: 1 day
REI: 48-72 hours
Use in IPM Programs: no information available
Use in Resistance Management Programs: It is used as part of a resistance management program
Efficacy Issues: no information available
Advantages: short pre-harvest interval
Disadvantages: no information available
Alternatives: Bt, which is reported to have medium efficacy, and pydrin (fenvalerate) and methomyl (carbamate), with high efficacy

Thiodicarb (Carbamate)

Formulations: Larvin 3.2 EC
Pests Controlled: diamondback moth, cabbage looper, and imported cabbageworm
Percent of Crop Treated: 100% of the farms, 100% of the acreage
Types of Applications: foliar treatment
Application Rates: 4 lb AI per acre
Number of Applications: six times in a growing season
Timing: Generally used in the last 4 weeks in rotations
Pre-Harvest Interval: 5 days
REI: 12 hours
PM Concerns: Hard on bees.(11)
Resistance Management Concerns: Need to rotate with Asana, especially if using four or more applications.(11)
Efficacy Issues: moderate knockdown and good residual control (11)
Advantages: Good insecticide to rotate with.

Disadvantages: Not effective if pH of water is not right.(11).
Alternatives: Thiodan (organochlorine), esfenvalerate (pyrethroid) and permethrin (pyrethroid) with good efficacy. The pyrethroids are not good when the weather is hot and humid.

Permethrin (Pyethroids)

Formulations: Ambush 2 EC or 25 WP, Pounce 3.2 EC or 25 WP
Pests Controlled: Aphids, Imported cabbage worm, Loopers, Thrips, Diamond black moths
Percent of Crop Treated: no information available
Types of Applications: foliar treatment
Application Rates: Ambush 2 EC 6.4 oz or 25 WP 6.4 oz., Pounce 3.2 EC, 4 oz or 25 WP6.4 oz
Number of Applications: no information available
Timing: before, at or after first flowering
Pre-Harvest Interval: 1 day
REI: 12 hours (11)
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: poor
Advantages: no information available
Disadvantages: Reflects an increase in chemical costs.(2) Very hard on bees.(3)
Alternatives: no information available

Cypermethrin (Pyrethroids)

Formulations: Ammo 2EC or Ammo WSB
Pests Controlled: Aphids, Imported Cabbage Worm, Loopers, Thrips
Percent of Crop Treated: no information available
Types of Applications: foliar treatment
Application Rates: Ammo 2EC 2.5 to 5 oz, or Ammo WSB 1-2 bags
Number of Applications: no information available
Timing: flowering
Pre-Harvest Interval: 1 day
REI: 12 hours
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: no information available
Advantages: Safer handling for harvest and applications
Disadvantages: no information available
Alternatives: no information available

Endosulfan (Organochlorine)

Formulations: Thiodan 3 EC, Phaser3 EC
Pests Controlled: Cabbage Loopers, Diamond Black Moth
Percent of Crop Treated: no information available
Types of Applications: foliar spray
Application Rates: 3 EC 2 pt or 50 WP, 1 1/2 lb
Number of Applications: no information available
Timing: at flowering or after
Pre-Harvest Interval: 7 days
REI: 24 hours (2)
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
Disadvantages:highly toxic to fish, corrosive to iron
Alternatives: no information available

Diazinon

Formulations: Diazinon 50 WP, Diazinon 500-AG, Diazinon 14 G
Pests Controlled: cabbage maggot
Percent of Crop Treated: no information available
Types of Applications: seedbed treatment, transplant water treatment
Application Rates: Diazinon 500-AG 1/2 to 1 pt, Diazinon 50 WP 1 lb/100 gal, Diazinon 14 G 21 lb, Diazinon 4 EC 3 qt
Number of Applications: no information available
Timing: no information available
Pre-Harvest Interval: not applicable
REI: 12-24 hours
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: good (2) (25)
Advantages: compatible with other pesticides (25)
Disadvantages: bird and bee toxicity (25)
Comments: Long residual time (25)

Malathion (Organophosphate)

Formulations: Malathion 57 EC
Pests Controlled: imported cabbage worm
Percent of Crop Treated: no information available

Types of Applications: foliar spray
Application Rates: 2 pt
Number of Applications: no information available
Timing: no information available
Pre-Harvest Interval: 3 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: no information available
Efficacy Issues: no information available
Advantages: no information available
Disadvantages: expensive

Carbaryl (carbamate)

Formulations: Sevin 80 S, Seven XLR Plus
Pests Controlled: imported cabbageworm, diamondback moth
Percent of Crop Treated: no information available
Types of Applications: foliar spray
Application Rates: Sevin 80 S 1 1/2 lb., Seven XLR Plus 1 to 2 qt
Number of Applications: no information available
Timing: no information available
Pre-Harvest Interval: 3 days
REI: 12 hours
Use in IPM Programs: no information available
IPM concerns: Kills beneficial insects. Excessive use leads to aphid outbreak
Use in Resistance Management Programs: Used as part of a resistance management program
Efficacy Issues: inexpensive yet effective
Advantages: s. It is an inexpensive yet effective product.
Disadvantages: no information available

Alternatives include: SpinTor, Di-Syston, Metasystox, Orthene

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Diseases

Downy mildew (*Peronospora parasitica*)

Biology

Downy Mildew is a moderate concern in Brussels sprouts. The initial symptom of this fungal disease is the appearance of small, irregularly shaped grayish-purple spots on stems and the undersides of leaves. Under cool, moist conditions the spots enlarge and become covered with fluffy, grayish-white mycelia. The upper surface turns yellow and dries out. Heavily infected leaves eventually drop off. The organism may move systemically in the plant causing internal darkening tissues. Downy mildew overwinters in plant debris or on cruciferous weed hosts. It spreads in the field with splashing water during cool, wet weather, and is primarily a problem during the fall. Fungicide applications help prevent spread of the organism in the field.

Cultural Controls

Rotation
Sanitation
Resistant cultivars
Well-drained soils

Chemical Controls

Mefenoxam/Chlorothalonil (Ridomil Gold, Bravo) at a rate of 1½ lb (REI 12 to 48 hrs)

- **Fosetyl-Aluminum (Maneb)**
  Aliette/Maneb 2+2 at a rate of 4 lb (PHI 7 days) (REI 24 hrs)
- **Fosetyl-Aluminum**
  Aliette WDG at a rate of 2 to 5 lb (PHI 3 days) (REI 12 hrs)
- **Metalaxyl + chlorothalonil**
- **Fosetyl-al**
- **Fosetyl-al + maneb B2**

Alternative Controls

No information available

Alternaria spp. Fungi

Biology

Alternaria is a fungus that causes leaf spotting and head rotting of crucifers. The initial disease symptom is the appearance of small dark spots on older leaves. The spots are generally circular, ranging from ½ to 1½ inches in diameter. A brown or black velvety mold, composed of masses of fungal spores, rapidly covers the lesion. These spores rub off the lesion surface easily. Lesions may coalesce to form large, irregular, diseased areas on the leaf surface. Leaf margins are often colonized by *Alternaria spp.* Plants are highly susceptible after tipburn or other injuries. Bacterial soft rot often follows *Alternaria* infection.

On cauliflower, tiny brown sunken lesions appear on the curds. On cabbage heads the lesions are yellow. The spots enlarge rapidly and are eventually covered with black spores.

Cultural Controls
To avoid Alternaria diseases, use high quality, disease-free seed; irrigate early in the day so that leaves dry rapidly; and tie cauliflower leaves as high as possible to allow air movement to reduce free moisture on the head. Apply fungicides when necessary.

Chemical Controls

- **Chlorothalonil**
  Bravo Ultrex 82.5 WDG 1.4 lb (PHI 7 days) (REI 48 hrs)
  Bravo Weather Stik or Bravo 720 or Supanil 720 or Terranil 6L at 1 ½ pt (PHI 0 days) (REI 48 hrs)
- **Copper Ammonium Carbonate**
  Copper Count N 8L at 2 qt (PHI 0 days) (REI 12 hrs)
- **Maneb**
  Manex at 1 1/5 to 1 3/5 qt (PHI 7 days) (REI 24 hrs)
  Maneb 75 DF or 80 WP at 1 ½ to 2 lb (PHI 7 days) (REI 24 hrs)
- **Copper Sulfate**
  Basicop 53 WP at 1 to 3 lb (PHI 0 days) (REI 24 hrs)
- **Copper hydroxide**
  Kocide 2000 at ¾ to 1 ½ lb (PHI 0 days) (REI 24-48 hrs)
  Kocide 101 or Kocide DF 1 to 2 lb (PHI 0 days) (REI 24-48 hrs)
  Kocide LF at 2 2/3 pt (PHI 0 days) (REI 24-48 hrs)
  Kocide 4.5 LF at 2.33 to 1 1/3 pt (PHI 0 days) (REI 24-48 hrs)
- **Fosetyl-Aluminum/Maneb**
  Aliette/Maneb 2+2 at a rate of 4 lb (PHI 7 days) (REI 24 hrs)
- **Mefenoxam/Chlorothalonil**
  Ridomil Gold/Bravo at a rate of 1½ (PHI 7 days) (REI 12 to 48 hrs)

Alternative Controls
No information available

Rhizoctonia solani

Biology
Rhizoctonia solani causes a number of closely-related diseases of cole crops, including damping off, wire stem, bottom rot, and head rot. If the fungus attacks very young seedlings, the disease is called damping off. The fungus penetrates seedlings near the soil line causing water-soaked constrictions of the

stem, which girdle the plant. The plants then wilt and topple over. If plants survive the initial attack, the center of the stem decays while the outer stalk provide sufficient support to keep the plants erect. At this stage the disease is called wire stem. Stems are brown or black and wiry above the soil line. The plants grow very slowly and usually do not develop to maturity. Bottom rot occurs as a carry-over from wire stem. *Rhizoctonia* can attack low lying leaves at the petioles and midribs. This produces reddish brown lesions, and the leave will eventually become slimy and brown while the disease progresses to inner leaves. Head rot may develop, causing a darkening and decaying of the stem at the base of the heads and spotting and wilting of the leaves in the center of the head.

Rhizoctonia overwinter as mycelium or sclerotia in the soil or on infected plant material. Once the pathogen is present in soil it remains there indefinitely. The pathogen can be spread through moving water, transport of contaminated soil and equipment and contaminated seeds and transplant seedlings. The disease develops more rapidly in moderately wet soils as opposed to saturated or dry soils. Plants that grow rapidly and vigorously tend to resist infection better than slow growing plants.

Cultural Controls

Control damping off and wirestem in the greenhouse and field seedbeds by using sanitized media and containers and avoiding overwatering. Whenever possible use disease free seeds, although infected seeds can be treated by hot water. Planting seeds on raised beds with good aeration between plants can decrease occurrence. A three year crop rotation will reduce infect rates. Do not grow cole crops in low-lying fields with heavy soils, use disease-free transplants.

Chemical Controls

Treat seeds or soil with a fungicide.

- Kodiak 0.1 - 0.5 oz/100 lb seed
- Fludioxonil (Maxim) 0.08 to 0.16 oz/100 lb seed
- Oxadixyl (Anchor) at 1 ½ oz/100 lb seed.
- Captan (30-DD or 300) at 1 ¼ oz/100 lb seed, or Captan (400 or 400-D) at 1 to 2 oz/100 lb seed. (REI)
- Thiram (42-S or 50 WP Dyed) is used as a seed treatment at a rate of 8 oz/100 lb seed. (REI 24 hours) (2)

Alternative Controls

Mulching and composting soils can reduce the disease. Biocontrol agents have also been used to control *Rhizoctonia*. The pathogen is parasitized by a variety of fungi including *Trichoderma*, *Gliocladium* and *Laetisaria* as well as predatory nematodes.

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Club root (*Plasmodiophora brassicae*)

Biology

Plasmodiophora brassicae is a protozoan that acts as a parasite on cruciferous plants. They are restricted to soil environments where they cause the formation of galls on susceptible plant roots. Club root can be a problem if the pH is below 7.2. Cells in the roots become enlarged and reproduce excessively forming large gall-like structures.

Club root is a fungal disease that attacks the roots of all cole crops and other cruciferous crops and weeds. Infected plants wilt in the middle of hot, sunny days, and leaves turn pale green to yellow. Eventually, infected plants wilt permanently and die, or survive in a stunted condition. Club root favors cool wet conditions

Swimming spores of the pathogen enter roots through root hairs or wounds. The organism stimulates plant cell multiplication, causing roots to enlarge and form spindle-shaped galls or "clubs." The growth of the clubs inhibits development of a normal root system and blocks the vascular system. The clubbed roots eventually decay and are invaded by soft rot bacteria that release a toxin. Lack of sufficient water and the presence of the toxin cause foliar wilting.

Cultural Controls

- Control pH – liming
- Rotation
- Sanitation
- Resistant cultivars

Clubroot incidence can be reduced by using uninfected transplants, avoiding movement of machinery from infested acres into clean fields, and maintaining a soil pH of 7.3 or higher. Crop rotation is not very effective because the resting spores can survive in the soil for many years.

Chemical Controls

- Terraclor F (PCNB) at a rate of 5.6 gal in 25 gal of water or 7.5 in 30 gal water (REI 12 hours)
- Terraclor 10G, 200 lb (row) or 300 lb (broadcast)
- Terraclor 75 W, 30 lb in 25 gal of water (REI 12 hours)

Alternative Controls

No information available

Blackleg (*Phoma ligam*)

Biology

Blackleg is most common on cole crops. Symptoms may appear early in the growing season on seedlings not yet transplanted in the field. Inconspicuous, small, circular, dark lesions appear on the leaves of the infected plants. The spots gradually enlarge, becoming well defined with a gray center filled with numerous black, pimple-like, spore-bearing structures called pycnidia. The lesions on stems are oval shaped and often surrounded by a purplish margin. Spots spread over the whole plant including the root system. The dark cankers which form on affected roots may eventually destroy the fibrous root system. The disease causes wilting, stunting, and death of infected plants.

It spreads with high rainfall, it is more of a concern in cool weather. It can also be a problem during crop storage.

Cultural Controls

To avoid blackleg, use disease-free seed and rotate fields out of cole crops for at least four years. Good aeration and drainage are important, good sanitation. Sheep manure can be a source of inoculum. Avoid herbicide damage, disease can be worse. Soak seed in 122° F water for 25 minutes.

Chemical Controls

No chemicals are registered for this disease.

Alternative Controls

No information available

Soft rot (*Erwinia carotovora*)

Biology

Soft rot bacteria cause a watery, soft, foul-smelling rot of the cole crops. Bacterial infection often occurs after chemical, mechanical, pest or other injury. It often follows external or internal tipburn. The bacteria soften the cell walls of plant tissue, which results in a rapid collapse into slimy mess. Soft rot may be a primary pathogen on cabbage heads, especially during warm, humid weather.

Cultural Controls

The bacteria become established in small droplets of water that remain on the heads. Cultivars with domed heads that shed surface water are less susceptible. To avoid soft rot, grow cole crops on well-drained soils and maintain adequate soil moisture to avoid tipburn. Select cultivars recommended for Michigan, and avoid injury to plants.

Chemical Controls

Chemical control of the disease is not suggested, however chemical control of pests may reduce the spread of the soft rot.

Alternative Controls
No information available

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Turnip mosaic virus and cauliflower mosaic virus

Biology
Turnip mosaic virus and cauliflower mosaic virus sometimes cause economic losses in stored produce. Early infection in the field cause leaf spotting and leaf drop. The spots become black and sunken on inner leaves during long-term storage. Turnip mosaic spots are larger than cauliflower mosaic spots. The viruses are transmitted by aphids. Aphid control is the primary means of virus control.

Cultural Controls
Select cultivars that are resistant to virus infection. Where the viruses have been a problem, make an extra effort to control curciferous weeds near seed beds.

Chemical Controls
Control aphids

Alternative Controls
No information available

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Fungicide Profiles

Chlorothalonil (Nitrile Compound)

Formulations: Echo, Daconil, Bravo (Bravo 500, Bravo Ultrex 82.5 WDG, Bravo Weather Stik, Bravo 720, Supanil 720, Terranil 6L)
Diseases Controlled: Alternaria Leaf Spot
Percent of Crop Treated: no information available
Types of Applications: spray
Application Rates: Bravo Ultrex 82.5 WDG 1.4 lb, Bravo Weather Stik or Bravo 720 or Supanil 720 or Terranil 6L at 1 ½ pt
Number of applications: no information available
Timing: when conditions favor disease development, every 7-10 days (2)
Pre-Harvest Interval: 0 days (2)
REI: 48 hours (2)
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available

Efficacy Issues: very effective
Advantages: broad-spectrum foliage protectant fungicide
Disadvantages: B2 carcinogen

Copper hydroxide (Inorganic Compound)

Formulations: Kocide, Champ Nu-Cop
Diseases Controlled: Black rot
Percent of Crop Treated:
Types of Applications:
Application Rates: Kocide 101 at 1 to 2 lb, Kocide 2000 at ¾ to 1 ½ lb, Kocide 4.5 LF at 2/3 to 1 1/3 pt, Kocide LF at 2 2/3 pt
Number of Applications: 1.2 applications
Timing: no information available
Pre-Harvest Interval: 0 days
REI: 24-48 hours
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: no information available
Advantages: a protectant for vegetables
Disadvantages: toxic to fish

Benomyl (Carbamate)

Formulations: Benlate SP or 50W
Diseases Controlled: White mold
Percent of Crop Treated: information not available
Types of Applications: foliar treatment
Application Rates: 2 lb ai/ac (2)
Number of Applications: no information available
Timing: 7 day intervals (2)
Pre-Harvest Interval: no information available
REI: 24 hours (2)
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: no information available
Advantages: preventative and eradicating fungicide, excellent residual activity(26)
Disadvantages: no information available

Thiram (Carbamate)

Formulations: Thiram 42-S or 50 WP dyed

Diseases Controlled: Damping off
Percent of Crop Treated: information not available
Types of Applications: seed treatment (2)
Application Rates: 8 oz/100lb seed (2)
Number of Applications: 1
Timing: for seed treatment
Pre-Harvest Interval: not applicable
REL: 24 hours
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: no information available
Advantages: It is a broad-spectrum pesticide and less expensive than alternatives
Disadvantages: no information available

Captan (Carboximide, Sulfenimide)

Formulations: Captan 30-DD or 300 or 400, 400-D
Diseases Controlled: Damping off
Percent of Crop Treated: no information available
Types of Applications: seed treatment
Application Rates: recommended (2) Captan 20-DD or 300 at 1 1/4 oz/100 lb seed, or Captan (400 or 400-D) at 1 to 2 oz/100 lb seed
Number of Applications: 1
Timing: seed treatment
Pre-Harvest Interval: not applicable
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: Captan is a B2 carcinogen

Fludioxonil (Organic Compound)

Formulations: Maxim 4 FS
Diseases Controlled: Damping off
Percent of Crop Treated: no information available
Types of Applications: seed treatment
Application Rates: recommended 0.08 to 0.16 oz/100 lb seed (2)
Number of Applications: no information available
Timing: seed treatment
Pre-Harvest Interval: no information available
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

Oxadixyl (Oxaolidinone)

Formulations: Anchor
Diseases Controlled: Damping off
Percent of Crop Treated: information not available
Types of Applications: seed treatment
Application Rates: recommended (2) 1 1/2 oz/100 lb seed
Number of Applications: no information available
Timing: seed treatment
Pre-Harvest Interval: no information available
REI: not applicable
Use in IPM Programs: no information available
Use in Resistance Management Programs: used in combination with other fungicides to reduce risk of resistance (26)
Efficacy Issues: no information available
Advantages: curative and eradicant (26)
Disadvantages: no information available
Comments: available in combination with fungicides to broaden spectrum of effect (26)

Terraclor (Chlorinate Hydrocarbon)

Formulations: Terraclor (PCNB) 10 G, Terraclor F, Terraclor 75 W
Diseases Controlled: Clubroot
Percent of Crop Treated: no information available
Types of Applications: seedbed treatment
Application Rates: Terraclor F 5.6 gal/25 gal water, Terraclor 10 G 200 lb in row or 300 lb broadcast, Terraclor 75 W 30 lb in 25 gal water or 40 lb in 35 gal water.
Number of Applications: no information available
Timing: seedbed application
Pre-Harvest Interval: not applicable
REI: 12 hours (2)
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: not effective for control of Pythium and Fusarium (26)
Advantages: no information available
Disadvantages: no information available

Fosetyl-Aluminum (Inorganic Compound)

Formulations:Aliette/Maneb 2 + 2, Aliette 80 W
Diseases Controlled: Damping off, Downy mildew and alternaria leaf spot
Percent of Crop Treated: <1%
Types of Applications: foliar
Application Rates: Aliette 80 W at a rate of 2 to 5 lb, Aliette/Maneb 2 + 2, 4 lb.
Number of Applications: no information available
Timing: 7 to 21 day intervals
Pre-Harvest Interval: 7 days
REI: 12 hours (2)
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: no information available
Advantages: gives long persistant control (26)
Disadvantages: no preventative action (26)

Mefenoxam/Chlorothalonil (Nitrile Compound)

Formulations: Ridomil Gold/Bravo
Diseases Controlled: Damping off and Downy mildew
Percent of Crop Treated: no information available
Types of Applications: foliar treatment
Application Rates:1 1/2 lb
Number of Applications: maximum 4 applications / crop
Timing: 14 day intervals
Pre-Harvest Interval: 7 day:
REI 12 to 48 hrs
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

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Nematodes

General

Biology

Nematodes are not a major economic concern in cole crop production in Michigan.(20) Sugar beet cyst, northern root knot and lesion nematodes can reduce broccoli yields. Fields with soil or root problems of undetermined cause should be tested for nematodes. If the above plant parasitic nematodes are present in population densities above the economic threshold for cabbage, crop rotation or application of nematicides are suitable for control of sugar beet cyst, root-knot and lesion nematodes in broccoli production. It is best not to plant broccoli on land infested with sugar beet cyst nematodes. (2)

Cultural Controls

Crop rotation with non-host crops. Corn and small grain crops are not hosts for root knot nematodes. (20) Sugar beet cyst nematodes have sufficient host specificity that rotation with non-hosts is generally an effective management practice. (20)

Chemical Controls

Nematodes can be controlled chemically through nematicide fumigations in the fall, preplanting soil treatment and soil treatment at planting.

- Fall soil fumigation (Broadcast)
- 1,3-D (Telone II) at a rate of 36 gal (muck soil), 15 gal (mineral soil) (2)

Chemical Controls

Nematodes can be controlled chemically through nematicide fumigations in the fall, pre-planting soil treatment and soil treatment at planting.

- Fall soil fumigation
- Preplant soil treatment
- Soil treatment at planting (2)

Nematicide Profiles

1,3-Dichloropropene (Fumigant)

Formulations: Telone II
Pests Controlled: nematodes and soil insects
Percent of Crop Treated: no information available
Types of Applications: Inject the fumigant to a soil depth of 8 inches and lightly seal the soil immediately after application, broadcast
Application Rates: of 36 gal (muck soil), 15 gal (mineral soil) is suggested (2)
Number of Applications: no information available
Timing: Fumigate in the fall, in some limited situations soil fumigants can be applied in the spring in Michigan (2)

Pre-Harvest Interval: not applicable
REI: 5 hours
Use in IPM Programs: no information available
Use in Resistance Management Programs no information available
Efficacy Issues: particularly effective against cyst forming nematodes and meadow nematodes. (20)
Advantages: also helps control weeds and diseases(20)
Disadvantages: cannot use on heavy soils(20)
Critical Use Issue: no information available

Fenamiphos (Organic Phosphate)

Formulations: Nemacur 15 G
Pests Controlled: nematodes and soil insects
Percent of Crop Treated: no information available
Types of Applications: The chemical is incorporated mechanically or with overhead irrigation (2)
Application Rates: (recommended rates) 7.3 to 18.4 oz per 1000 row feet in 6 – 15 inch band width (2)
Number of Applications: no information available
Timing: Application may be made prior to planting, at planting or immediately following transplanting.(2)
Pre-Harvest Interval: not applicable
REI: 48 hours
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: no information available
Advantages: contact soil nematicide-insecticide (24)
Disadvantages: no information available
Critical Use Issue: no information available

Ethoprophos (Fumigant)

Formulations: Mocap 6 EC
Pests Controlled: nematodes and soil insects
Percent of Crop Treated: no information available
Types of Applications: Fumigant
Application Rates: (recommended rates) Preplant soil treatment: Mocap 6 EC at 3.3 qt. or 10G, 50 lb. At planting: Mocap 6 EC 1.3 to 2 qt (36 inch row spacing) or 10 G, 20 lb (36 inch row spacing) applied in a 12- to 15-inch band over the row (2)
Number of Applications: 1
Timing: applied prior to one week before planting or as a soil treatment at planting (2)
Pre-Harvest Interval: not applicable
REI: 48 hours

Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: no information available
Advantages: contact nematicide and insecticide
Disadvantages: no information available
Critical Use Issue: no information available

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Weeds

Weed control is important for the control of diseases and pests. Weeds in the *Brassicaceae* family, such as wild mustard, yellow rocket, shepherdspurse, and wild radish need to be eliminated because they serve as hosts for several cole crops diseases. Weeds such as yellow rocket and mustard are hosts for cabbage maggots. Weeds can be a severe problem in Brussels sprouts because it is a long season crop. If cultivation is used to control weeds, care should be taken to avoid root damage.

Crop rotation, cultivation and herbicide applications help to control weeds. Herbicide can be applied either before planting and incorporate into the soil or after seeding. Other herbicides can be applied after crop emergence.

Cultural Controls

- Crop Rotation
- Cultivation

Chemical Controls

- Paraquat (Gramoxone extra)
- Trifluralin (Treflan)
- Napropamide (Devrinol 50DF)
- Oxyfluorfen (Goal 2XL
- Sethoxydim (Poast 1.5E)
- Glyphosate (Roundup)

Alternative Controls
No information available

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Herbicide Profiles

Trifluralin (Dinitroanaline Compound)

Formulations: Treflan 4E, Trilin 4E
Weeds Controlled: to control broadleaves and annual grasses
Percent of Crop Treated: no information available
Types of Applications: incorporated into soils for pre-plant weed control on mineral soils
Application Rates: 0.81 pounds per acre, rates increase with increasing clay and organic content in Number of Applications: 1.0 applications
Timing: Preplant incorporation
Pre-Harvest Interval: not applicable
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: Good herbicide Primarily a grass herbicide; 3-4 weeds residual activity
Advantages: Cheap, selective and effective
Disadvantages: not very effective on muck soils, short residual period; may cause root stunting.

Paraquat (bipyridylium)

Formulations: Gramoxone, Extra 2.56
Weeds Controlled: emerged weeds
Percent of Crop Treated: <5%
Types of Applications: Preplant
Application Rates: 1 pt. per 100 gal; suggested 0.7-1 lb ai
Number of Applications: 1
Timing: before seeding or transplanting and incorporated to a depth of 2-3 inches, also applied after planting
Pre-Harvest Interval: not applicable
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: Weak herbicide
Advantages: No root stunting
Disadvantages: Expensive, weak, irrigation should occur within 24 hours of application

Napropamide (Amide)

Formulations: Devrinol 50 DF
Weeds Controlled: germinating grasses and broadleaves
Percent of Crop Treated: 5%
Types of Applications: Preplant
Application Rates: 1-2 lb ai

Number of Applications: 1
Timing: before seeding or transplanting and incorporated to a depth of 2-3 inches, also applied after planting
Pre-Harvest Interval: not applicable
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: Weak herbicide
Advantages: No root stunting
Disadvantages: Expensive, weak, irrigation should occur within 24 hours of application

Sethoxydim (Cyclohexenone)

Formulations: Poast 1.5 E
Weeds Controlled: Emerged grasses
Percent of Crop Treated: 50%
Types of Applications: no information available
Application Rates: 0.19 to 0.28 lb ai/ac
Number of Applications: 1
Timing: applied to actively growing grasses
Pre-Harvest Interval: 30 days
Use in IPM Programs: no information available
Use in Resistance Management Programs: no information available
Efficacy Issues: good herbicide
Advantages: Kills emerged grasses, effective, inexpensive
Disadvantages: no residual control, poor control of quackgrass

Glyphosate (Phosphono amino acid)

Formulations: Roundup 4L
Weeds Controlled: wide spectrum weed control, perennial weeds after they have emerged
Percent of Crop Treated: 10%
Types of Applications: Pre-plant
Application Rates: 2-3 lb
Number of Applications: 1
Timing: Apply either before planting in the spring or after harvest in the fall.
Pre-Harvest Interval: not applicable
Use in IPM Programs: no information available
Use in Resistance Management Programs: Kills emerged weeds
Efficacy Issues: kills most emerged weeds
Advantages: Kills perennial weeds
Disadvantages: Can’t be used in crops, no residual

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