Crop Profile for Cabbage in Wisconsin

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General Production Information

In 2001 there were 4,500 acres of fresh market cabbage planted in Wisconsin. Of this acreage, 4,300 acres were harvested with an average yield of 100 cwt per acre -- a 10 cwt reduction from the previous year, resulting in an 11% overall production decrease. The value of fresh cabbage for 2001 was $7.20 per cwt with a total value of $5.8 million. Commercially-grown cabbage destined for fresh market consumption is usually sold as cole slaw.

An additional 3,700 acres of cabbage was grown for kraut in 2001 with 3,600 of the planted acres harvested. Yield per acre was 22.63 tons. The combined decrease of 100 fewer harvested acres and a 5.34 ton per acre drop resulted in a 21% total reduction. Kraut cabbage sold for $47.00 per ton in 2001 with a total crop value of $3.8 million.

Wisconsin ranks 7th in the U.S. for fresh market cabbage production and 2nd behind New York, in kraut cabbage production.

Other cole crops such as broccoli, cauliflower, Brussels sprouts, kohlrabi, rutabagas, and kale are also grown in Wisconsin but on limited acreage primarily for fresh market sale and won't be addressed in this profile.

Production Regions

Most of the cabbage grown in Wisconsin is either grown in Outagamie county in the east central part of the state or in Racine, Kenosha, and Waukesha counties in southeastern Wisconsin.

Cultural Practices

Cabbage is a cool season crop and may be planted early or late during the growing season. Fresh market cabbage grown in the state may be red or green. Leaf texture may be smooth or savoy (crinkled). Processing varieties are typically have larger heads with tightly packed leaves than those grown for fresh market. Common processing varieties include Bravo, Score and Hi Nova.

Cabbage is grown on a variety of soils but performs best on well-drained, fertile, loam. Early crops perform better on sandy loam soils because these soils warm up more quickly in the spring. Optimum soil pH should be above 6.6 to maximize yield and prevent disease problems. Annual soil tests will indicate whether supplemental fertilizer

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applications are required. Nitrogen is applied prior to planting and phosphorus and potassium levels are also adjusted at this time according to soil test recommendations.

The field is prepared the previous fall for early season crops to avoid planting delays in the spring due to cold weather or wet soils. It is important not to overwork soils as this may result in crusting at planting time. Almost all of the commercial cabbage production in Wisconsin is grown from either bare root transplants or plugs however there are about 500 acres in the state that are direct seeded. Transplants are set out in late April. The only supplemental water provided to the crop is the transplant water used at planting after which there is no irrigation for the remainder of the season.

While plants are still young, the field is cultivated once or twice to control emerging weeds.

All processed cabbage in Wisconsin is machine harvested while some of the fresh market cabbage is hand harvested.

Insect Pests

Cabbage Looper (*Trichoplusia ni*) represents the major annual economic pest that causes damage hat may be extremely severe in certain years. Populations fluctuate from year to year based on dispersal patterns. It is one of the three pests that make up the caterpillar complex. Cabbage loopers do not overwinter in significant numbers in northern states but migrate up from the south from mid-June through September. There are 1-3 generations per year. White eggs are laid singly on the lower leaf surface in July and larvae mature through five successively larger instars over a period of 2-4 weeks before pupating. Adults emerge 10-14 days later, mate, and lay eggs that give rise to the second generation which causes damage in late summer. It is the larger, second generation that causes the most damage to the fall cabbage crop in Wisconsin.

The larvae feed on the wrapper leaves between the large veins and midribs. As the cabbage matures and head formation is well advanced, loopers will eat through several layers of cabbage leaves and feed on the succulent tissue within. The accumulation of frass is also a contamination problem.

Diamondback Moth (*Plutella xylostella*) This is another member of the lepidopterous insect pest complex that causes economically-significant damage on cabbage grown in Wisconsin. It may become a major pest if insecticide-resistance is present in the population, however in most years it’s numbers are kept low through parasitism. A few diamondback moths may overwinter as cocoons on plant debris in Wisconsin; however, the bulk are brought into the state as larvae on transplants grown in southern states. Adults emerge in early spring and infest cruciferous weeds or early cole crop plantings. Eggs hatch in 4-5 days and first instar larvae mine leaves. Young larvae feed externally on the lower leaf surface, leaving the upper surface intact. The most severe and important damage occurs when larvae disfigure the developing bud on young cabbage, resulting in head abortion. Feeding damage also encourages the invasion of soft rot bacteria. Head boring is also common in early cabbage and can result in unmarketable heads. Diamondback moths pupate on the lower leaf surface. There are 3-4 generations per year in Wisconsin.

Imported cabbageworm (*Pieris rapae*) This is the third member of the caterpillar complex. Although it’s a serious pest in Wisconsin, it’s easier to control than the other two caterpillar pests. However, it has shown resistance to organochlorine insecticides in the past and there is concern over developing resistance to synthetic pyrethroids. Imported cabbageworms overwinter as pupae. The emerging adults mate and lay single eggs on cruciferous weeds or early cole crop plantings. Within a week, the eggs hatch into first instar larvae. Over the next two weeks, the larvae feed until they reach an ultimate length of approximately 1½ inches. The adults from this generation appear in cabbage fields in early summer and begin laying 2nd generation eggs. The 2nd generation larval population is the largest and most

destructive. The 3rd generation of larvae are present in late summer and is often greatly reduced by bacterial and fungal diseases and parasitoids. There are typically three generations per year in Wisconsin.

Damage results when the larvae feed on the wrapper leaves removing tissue between the midribs and large veins. As older larvae move toward the center of the plant, they may remove all but the main leaf veins. Large, irregular holes are the characteristic damage of the imported cabbageworm. Large amounts of frass produced by the larvae contaminates the heads making this a serious issue in fresh market production.

Cabbage Maggot (*Delia radicum*) is a sporadic pest of cabbage. Early season transplants and late season seedlings are most severely damaged. The first generation of the three generations is the most serious and populations can build when predictive models aren't used to determine when the first generation will appear. Cabbage maggots overwinter as pupae in the top five inches of soil. Adults emerge in early May (300 DD_{43}) and lay eggs on the soil close to transplants. The eggs hatch in 3-7 days and larvae feed on plant roots for 3-4 weeks before pupating in the soil. A total of 1180 DD_{43} are required to complete the first generation. The second generation appear in mid-summer (June-July) and lay third generation eggs that develop into the overwintering pupae in the fall.

Cabbage maggots feed both internally and on the root surface, introducing diseases that may kill the plant or render it unmarketable. Maggots can be especially damaging to seedlings, injuring the root meristem and thereby stunting plant growth. Affected plants appear stunted and off-color. Severely-damaged plants may wilt during hot weather. Damage caused by the cabbage maggot can provide a point of entry for soft rot bacteria and fungal pathogens.

Seed Corn Maggot (*Hylemya platura*) may attack early season transplants or root crops causing similar damage to that caused by cabbage maggots. Seed corn maggots overwinter as pupae and adults emerge prior to cabbage maggot adults ($125DD_{3.9C}$). Eggs are laid in the soil close to susceptible crops or organic matter and after 3-6 days, the eggs hatch and larvae feed for 3-4 weeks before pupating. There may be 4-5 generations in Wisconsin with the most severe damage resulting from the first and second generations. The seed corn maggot is typically not economically important.

Cabbage Aphids (*Brevicoryne brassicae)* Economic damage caused by the cabbage aphid is sporadic and most severe in hot, dry weather. It overwinters as fertilized eggs on crop debris from the previous season. Throughout the season, wingless females parthogenetically produce multiple generations per year with each female typically produces 80-100 offspring. When food becomes scarce, winged females are produced to disseminate the species to other sites. Dry weather favors the build up of cabbage and turnip aphids.

Late in the season as cabbage aphid numbers increase, plant leaves will cup or curl up from loss of plant sap. Foliage of heavily infested plants is stunted, light in color, and contaminated with insect parts and waxy debris. The cabbage aphid is a vector of several viruses, although these are seldom a problem in Wisconsin.

Fleabeetles (*Phyllotreta spp.*) are an occasional pest of cabbage however, they can be particularly damaging on early season fresh market cabbage. The striped, crucifer, and western black fleabeetles are the primary species. They overwinter as adults in the soil or beneath plant debris. The beetles become active when temperatures reach 50°F and feed on weeds or volunteer plants until the crop is planted. Adults begin laying eggs in the soil at the base of host plants in the spring with egg hatch occurring one to two weeks later. A complete life cycle takes 30-50 days and there are usually two generations per year.

Adults feed on both leaf surfaces but usually on the underside where they chew small (less than ⅛ inch), circular holes through tissue to the upper cuticle which often remains in place for some time before drying and falling out. The circular hole gives the plant a shotgun-blast appearance characteristic of fleabeetle injury. Heavy feeding on young plants may reduce yields or even kill plants in severe cases. Larvae feed on plant roots but do not cause economic damage. Control

of fleabeetles is critical prior to the third leaf stage.

Onion Thrips (*Thrips tabaci*) is a sporadic pest on cabbage and is economically important on some varieties, particularly those varieties with extremely dense heads. Red varieties are usually less susceptible. Adults and nymphs overwinter on plants or debris, along weedy field edges or in alternate crops such as clover, alfalfa, or wheat. The females reproduce without mating and lay eggs beneath the leaf surface. Eggs hatch after 5-10 days and nymphs are fully grown after 15-30 days. There are usually 5-8 generations of thrips per year. Thrips are often found in protected sites inside the head where they are out of reach of insecticides and many natural control agents.

Thrips typically show up mid-season and pose a problem both in the field and in storage. There are no insecticides available for thrips management that won't disrupt an IPM program for other pests. Thrips primarily damage crops directly when they feed. Thrips damage can be a serious problem on kraut cabbage where there is a necrotic flecking of the internal tissues and white blisters on the outer leaves of raw cabbage that show up as dark blotches on the processed kraut. Heavy thrips build-up inside the cabbage head may cause the head to be distorted.

Chemical Controls for Insect Pests in IPM and Resistance Management Programs

The lepidopteran insect pest complex are the most damaging pests of cole crops grown in Wisconsin, and IPM programs must be designed to manage this complex. Management strategies for the other, sporadic pests should be designed to provide effective control when needed without disrupting management programs targeted at the lepidoptera.

Insecticide resistance is a key concern with lepidopteran pests on cole crops. For example, extensive resistance to organophosphate, pyrethroid, and carbamate insecticides has been documented in the diamondback moth in nearly every major growing region, worldwide. In the Midwest, resistant larvae are often transported into Minnesota and Wisconsin on transplants from the southeastern U.S. Thus the occurrence of resistant populations is unpredictable and dependant on previous insecticide regimes on seed beds or in greenhouses in the southern U.S. However, a recent 2001 survey in Minnesota did not detect pyrethroid or Avaunt (indoxacarb) resistance in diamondback moths or cabbage looper (Liu et. al., in review). Diamondback moth resistance to Bt has also been documented in parts of the U.S. where use has been extensive, but to date, no Bt resistance has been found in Wisconsin. Although resistance to currently-used insecticides has not been reported in the imported cabbageworm and cabbage looper populations in Wisconsin, extensive resistance to chlorinated hydrocarbons was present in the 1950s and widespread damage resulted; IPM programs should thus reflect the potential for resistance in all lepidopteran species.

Lepidopteran Complex - (Diamondback Moth (DBM), Imported Cabbageworm (ICW), and Cabbage Looper (CL))

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Significant rates of natural parasitism have been reported for the lepidopteran pest complex (Mahr et. al. 1993). Since

parasitism is a significant mortality factor and resistance to commonly used insecticides is a serious concern. IPM programs which avoid broad-spectrum insecticides early in the season in favor of lepidopteran-specific insecticides such as Bt or Spinosad can preserve beneficial insects and achieve control while avoiding early season selection for resistance.

To further refine control and avoid undue selection pressure from unnecessary applications, scout cole crops weekly and control applications applied only when thresholds are surpassed. Infestation thresholds have been developed for cole crops. The threshold varies by crop growth stage and may be adjusted as required to meet specific market requirements. The following thresholds are designed to provide a marketable product for fresh market.

Percent Larval Infestation Threshold		
Growth Stage	**Cabbage**	**Cauliflower & Broccoli**
Seed Bed	10%	10%
Transplant to cupping (cabbage)	30%	-
Transplant to first flower or curd flower or curd	-	50%
Cupping, first flower/curd to heading	20%	10%
Mature head	10%	10%

Effective IPM programs for this complex should prevent damage, encourage natural control and avoid resistance. The following elements should be included:

1. Use transplants which are free of larval contamination
2. Scout the crop weekly and apply insecticides only at threshold levels which vary by crop maturity.
3. Target early instar larvae and insure good plant coverage to improve efficacy.
4. Use pest-specific insecticides in early to mid season when diamondback moth and imported cabbageworm are prevalent to conserve natural enemies.

    - Wisconsin growers treat over 90% of the commercial cole crop acreage with an insecticide to control lepidopteran larvae.

Pyrethroids are the most widely applied insecticides for worm control on cole crops in Wisconsin. They comprise the primary management tool along with reduced-risk products. It’s important to rotate chemical families for resistance management. One concern over the use of pyrethroids is their negative impact on natural enemies; another is it’s likelihood to cause flare ups of diamondback moths due to the high level of pyrethroid resistance in diamondback moth populations. Pyrethroid activity is broad spectrum and multiple applications (3-5) are commonly made. The most effective IPM use pattern for pyrethroids in Wisconsin is for mid-late season applications targeted at lepidopteran larvae, particularly cabbage loopers. All pyrethroid formulations used in Wisconsin are restricted use due to fish toxicity and product selection is based on persistence, efficacy, and price. Between the numerous products available, it’s difficult to choose between them as they are all equally effective however the longer residual of lambda-cyhalothrin (Warrior) and bifenthrin (Capture) may result in their being favored by cabbage growers. The following formulations are used:

- **Bifenthrin** (Capture) provides good to excellent control of the imported cabbageworm, cabbage looper, diamondback moth, and fleabeetles and provides good control of the cabbage aphid and thrips if applied before the thrips enter the head. Bifenthrin is hard on natural enemies and interrupts IPM programs for lepidopteran pests if used early in the season. Bifenthrin is used at a rate of 0.033-0.1 lb a.i./A with a pre-harvest interval of 7

days.

- **Esfenvalerate** (Asana) is another synthetic pyrethroid insecticide that provides good control of the imported cabbageworm, cabbage looper, diamondback moth, and fleabeetles and provides good control of the cabbage aphid and thrips if applied before the thrips enter the head. Asana was used widely before the registration of Warrior at which time it's use has declined. It is the weakest of the synthetic pyrethroid insecticides. Use rates are between 0.015-0.05 lb a.i./A with a 3-7 day PHI.

- **Fenpropathrin** (Danitol) provides good to excellent control of the cabbage looper and imported cabbageworm. Use rates between 0.2-0.3 lb a.i./A are recommended and there is a 7 day PHI.

  Lambda-cyhalothrin (Warrior) provides good control of lepidopterous larvae, fleabeetles, aphids, and onion thrips at rates from 0.02-0.03 lb a.i./A with a pre-harvest interval of one day.

- **Cypermethrin** (Ammo) is a broad-spectrum pyrethroid registered for the control or suppression of a wide range of pests on cabbage only at 0.05 to 0.1 lb a.i./A with a 1 day pre-harvest interval.

- **Zeta-Cypermethrin** (Fury) is a broad-spectrum pyrethroid that provides good control of a wide range of cabbage pests at 0.028-0.05 lb a.i./A with a one day pre-harvest interval.

Organophosphate insecticides have been largely replaced by synthetic pyrethroids for lepidopterous larvae on cole crops in Wisconsin. The high toxicity of organophosphates and the existence of resistance in diamondback moth in the southern US were contributing factors in this decline. The need for organophosphates in lepidopteran control on cole crops has diminished with the pending availability of several lepidopteran-specific materials that are in development. Registered organophosphates that may still be applied for lepidopteran control include:

- **Diazinon** (Diazinon) is a broad-spectrum organophosphate insecticide that has not been used because of resistance problems since the 1970s.

- **Naled** (Dibrom) is a short-residual organophosphate with activity on lepidopteran larvae at 1.0-2.0 lb a.i./A. Dibrom use is limited to cleanup applications close to harvest due to its limited persistence and 1 day PHI. However it's not often used because it is costly, has poor efficacy, and there are resistance problems in some species. Synthetic pyrethroids have replaced the use of naled in cabbage.

- **Carbamate** insecticides have also been largely replaced by pyrethroids for lepidopterous larval control on cole crops due to concerns over toxicity and resistance. The broad-spectrum activity of carbamates resulting in suppression of beneficial insects is not suited for IPM programs and therefore carbamate use is restricted to late season applications where resistance is not a threat. Registered carbamates include:

- **Carbaryl** (Sevin) is a carbamate with long standing registrations on cole crops for lepidopteran larvae, and fleabeetle control at 0.5-2.0 lb a.i./A with a 3 day PHI. It can be effective if timed correctly; when larvae are small but it's hard on beneficial insects and will cause aphid populations to flare. Limited persistence relative to pyrethroids has limited the use of carbaryl in Wisconsin however because it is not a restricted-use product, several market gardeners still use carbaryl for insect control in cole crops.

- **Methomyl** (Lannate) is a broad-spectrum carbamate with fair lepidopteran activity applied at 0.225-0.9 lb a.i./A with a 1-3 day pre-harvest interval depending on the crop. Cabbage looper control is poor and it must be applied when cabbageworms and diamondback moths are small if any activity is to result. Resistance concerns and

limited persistence has reduced Lannate use in the state.

- **Thiodicarb** (Larvin) is a short-residual, broad-spectrum carbamate with activity on lepidopterous larvae at 0.4-1.0 lb a.i./A with a PHI of 7 days. There have been spotty reports of resistance by diamondback moths to this product.

Reduced Risk Insecticides

- **Spinosad** (SpinTor) provides good to excellent control of lepidopteran pests and is the primary control used for diamondback moth. SpinTor is used in rotation with synthetic pyrethroids because the label has distinct resistance management criteria. Rates may vary according to the predominant target species. SpinTor does not disrupt natural enemies and is thus a good fit for early-mid season control in IPM programs. To manage resistance, applications are limited to two per generation. There may also be some thrips suppression.

- **Emamectin benzoate** (Proclaim) provides good control but is expensive to use. It was registered recently and there is not a lot of experience with the product's use in Wisconsin to date.

- **Indoxocarb** (Avaunt) is another new product with little experience to date. It is not as good as the other products at controlling loopers but it provides good control of imported cabbageworms and diamondback moths. It is recommended at a rate of 0.045-0.065 lb a.i./A and has a 3 day pre-harvest interval.

- **Tebufenozide** (Confirm) provides good control of lepidopterous pests of cole crops at a rate of 0.09-0.12 lb a.i./A. It has a 7 day pre-harvest interval however, control on diamondback moths may be poor.

- ***Bacillus thuringiensis*** (MVP, Javelin, Dipel) provides fair to good control if timed properly, especially in the case of cabbage looper. It requires multiple applications to be effective because of its short residual. A few formulations of Bt are suitable for use by organic vegetable growers and as a result, this tool is necessary for cabbage production. Rates of application vary with the product and formulation but all products can be used right up until the day of harvest.

Other Insecticides

- **Endosulfan** (Endosulfan, Phaser, Thiodan), is an organochlorine insecticide with broad-spectrum activity that is not used much but is registered for lepidopterous larval control. Control is only poor to fair at the labeled rates of 0.75-1.0 lb a.i./A with a 7-14 day PHI.

Cabbage Maggots

Cabbage maggots frequently require management in areas of intensive cole crop production where isolation through crop rotation is not possible. IPM strategies for root maggot reduction include the following:

1. Rotate cole crop fields to avoid infestation.
2. Predict first generation fly oviposition using degree days or phenology (eg. cabbage maggot oviposition coincides with lilac bloom) and avoid planting during peak egg-laying periods.
3. If insecticidal protection is required, direct applications at the base of the plants to avoid disruption of soil-inhabiting beneficial insects.

Since most commercial cole crop production is on rotated land, insecticide use is limited to 25-30% of the acreage in Wisconsin. Registered materials are all organophosphates, however, and thus *resistance is a major concern***.** There are no non-organophosphate alternatives for root maggot control. Registered materials for soil application include:

Organophosphate Insecticides

- **Chlorpyrifos** (Lorsban) is the primary material used for cabbage maggot control in Wisconsin. Lorsban is directly applied to the base of transplants at 1.6-3.3 fl oz/1000 feet of row for the liquid formulation and at 4.6-9.2 oz/1000 feet of row for the granular formulation with a PHI of 30 days. There is a concern about the development of resistance as there are no alternative materials for cabbage maggot control.

- **Diazinon** (Diazinon) is a short-residual organophosphate with fair root maggot efficacy at 0.125-0.25 lb a.i./A as a transplant water drench or 2-3 lb a.i./A as a broadcast spray. Little diazinon is used for root maggot control in commercial production in Wisconsin.

Aphids

Aphids are a sporadic pest on cole crops grown in Wisconsin with the cabbage aphid being the most destructive. IPM strategies for aphids include the following:

1. Scout crop regularly to detect early infestations and follow these to determine whether natural controls will suppress populations.
2. If treatment is necessary, take care not to disrupt natural control for lepidopteran pests.

Since no specific aphidicides are currently available, broad-spectrum materials with aphicidal activity may be necessary. The following insecticides are registered:

Pyrethroid insecticides used primarily for lepidopterous larval control on cole crops also provide fair to good suppression of aphid populations and frequently prevent outbreaks. Examples of pyrethroids with aphid activity include lambda-cyhalothrin, bifenthrin, zeta-cypermethrin, and fenpropathrin. Although pyrethroid use is extensive, these materials are rarely targeted at aphids specifically and will wipe out populations of beneficial insects.

- **Bifenthrin** (Capture) is recommended for aphid control at a rate of 0.033-0.1 lb a.i./A. It provides good control but is hard on natural enemies and as such, interrupts IPM programs for lepidopteran pests when used early in the season. There is a 7-day pre-harvest interval.

- **Lambda-cyhalothrin** (Warrior) is the least effective synthetic pyrethroid labeled for aphid control on cabbage. It provides fair control at best. Because it is also hard on beneficial insects and disrupts IPM programs, it is not used as often as the other insecticides in this class.

- **Zeta-cypermethrin** (Mustang) also only provides fair control of aphids. It’s registered for use at rates of 0.04-0.05 lb a.i./A and can be used up to 1 day before harvest.

Organophosphate insecticides include several materials registered for aphid control including diazinon, dimethoate, disulfoton (soil application), and oxydemeton-methyl. These materials are broad-spectrum and are likely to disrupt

beneficial arthropods that may be important for aphid and lepidopteran larvae control. Organophosphate use for aphid control in Wisconsin is limited to serious outbreaks and constitutes a minimal amount of the cabbage acreage.

- **Diazinon** (Diazinon) provides fair aphid control in cabbage. It is inexpensive to use and is hard on beneficial insects. However its short pre-harvest interval and non-restricted use status makes it attractive for use by market growers. It is recommended for aphid control at a rate of 0.25-0.5 lb a.i./A with a PHI of 5-14 days.

- **Dimethoate** (Dimethoate) is a systemic insecticide that provides fair to good control of cabbage aphids. Like other organophosphate insecticides, it is hard on beneficial insects. It's low cost and short residual make it attractive for use. Rate of application is recommended at 0.25-0.5 lb a.i./A with a 7-14 day PHI.

- **Disulfoton** (Di-Syston) is a soil-applied, systemic insecticide that provides good aphid control at rates pf 1 lb a. i./1000 ft of row in the furrow at planting.

- **Oxydemeton methyl** (Metasystox R) provides good control of cabbage aphids at rates of 0.375-0.75 lb a.i./A and a 7-10 day PHI.

Other Insecticides

- **Imidacloprid** (Provado, Admire) is a nicotinyl insecticide with low toxicity which has systemic activity and good efficacy on aphids. Admire may be applied as a soil treatment at 14-20 fl. oz./A while Provado is applied as a foliar spray at 6.6 fl. oz./A. Imidacloprid is a viable alternative to organophosphates for aphid control but use is limited since the key lepidopteran pest complex is not controlled with this product.

- **Endosulfan** (Endosulfan EC, WP; Phaser EC, WP; Thiodan EC, WP), an organochlorine with aphid activity at 0.75 - 1.0 lb a.i./A with a 7-14 day PHI depending on the crop. Endosulfan use on cole crops is limited in Wisconsin.

- **Potassium salts of fatty acids** (M-Pede) is a low-toxicity alternative to organophosphates for aphid control on cole crops, however, efficacy is low so it is not frequently used in Wisconsin other than by organic growers.

Fleabeetles

Fleabeetles are sporadic cabbage pests but can be a serious pest of early, direct-seeded cabbage. IPM strategies for fleabeetles include:

1. Scout crop regularly to determine the need for treatment.
2. If treatment is needed, materials should be selected which will not disrupt natural enemies of other pests e.g. lepidoptera.
3. When possible, apply needed controls early in the season using non-persistent materials to avoid negative impacts on natural controls.

The following materials are registered for fleabeetle control:

Pyrethroid insecticides, although used primarily for lepidopterous larval control, pyrethroids generally provide good control of fleabeetles also. When used early in the season, you can avoid the negative impact of broad-spectrum activity on beneficial arthropods. Zeta cypermethrin and bifenthrin both provide good to excellent control of fleabeetles.

Organophosphates Disulfoton, as an in-furrow treatment provides good fleabeetle control but is rarely used to target this pest.

Carbamates (carbaryl and thiodicarb) provide excellent fleabeetle control but should be used only early in the season due to negative impacts on beneficial organisms. Because of this restricted timeframe, little carbamate use occurs.

Thrips

Thrips are a sporadic pest in Wisconsin with kraut cabbage being the most susceptible crop. Thrips can cause problems in storage as well as in the field. No registered insecticides provide consistent thrips control because of the protected niches frequented by the thrips and widespread resistance (in onion crops). Follow these thrips management strategies to obtain control while avoiding disruption of management programs for other pests:

1. Select a thrips-tolerant variety where feasible. Lists of varietal susceptibility to thrips are available from the Cornell University Agriculture Experiment Station.
2. Avoid plantings adjacent to small grain or alfalfa crops that may serve as sources of heavy thrips infestation during harvest.
3. Scout crops or use sticky traps to determine when thrips activity is high.
4. Apply insecticidal controls if needed only to susceptible varieties that are infested prior to head formation (cupping).

The following insecticides are available for thrips control, although consistent control is seldom achieved:

Pyrethroids (bifenthrin, cypermethrin, zeta-cypermethrin, and lambda-cyhalothrin) provide good thrips control when timed appropriately and will not disrupt IPM programs if used mid-season. There has been extensive resistance detected in late season thrips populations in onion following pyrethroid use and thus growers should avoid repeated use in cabbage.

Organophosphates (disulfoton) can be used for thrips control but is not used because of poor efficacy and resistance problems**.**

Other Insecticides

- **Spinosad** (SpinTor) is a new chemistry with some thrips activity that may suppress populations without disruption of natural control although field efficacy has not been determined on cabbage.

Weeds

Weed management is essential in cabbage production for maximum yields. Key weeds in Wisconsin cabbage production include lambsquarters, pigweed, velvetleaf, the latter presenting a serious problem. Problematic annual grass weeds include foxtails and barnyardgrass.

Before planting, reduce or eliminate perennial weeds. In most cases, early season cole crops mature before annual weeds become a problem, however, control winter annual weeds, particularly those belonging to the mustard family, prior to planting. Early in the season, growers should use cultivation to control seedling weeds as they occur. However,

as the crop develops, cultivation may damage the shallow root system of the crop, at which time growers use herbicides if weeds exceed threshold levels.

Annual broadleaf weeds that pose a problem in cole crop production include lambsquarters, pigweed, and velvetleaf. Lambsquarters (*Chenopodium album*) is a very adaptable weed that sets thousands of seeds that can remain in the soil for many years. It thrives on all soil types and over a wide range of disturbed habits. It can germinate throughout the growing season but most seed germinates early and growers should target control at this time. Lambsquarters is a vigorous competitor for nutrients. At this time there has been no herbicide resistance in lambsquarters.

Three pigweed species can cause problems in cabbage production: redroot & prostrate pigweeds and waterhemp. All three are vigorous competitors that produce a very large number of seeds that can survive in the soil for up to 40 years. Fields with a history of pigweed must have pre-emergence or early post-emergence herbicides applied along with early season cultivation to prevent outbreaks in the current season. Of the three, waterhemp is the most difficult to control.

Velvetleaf (*Abutilon theophrasti*) is a serious problem in the production of cole crops. It is a very strong competitor on the best soils, shading crop plants and robbing them of moisture and nutrients. Because if its height it creates a high humidity in the crop canopy thus resulting in disease development. Velvetleaf can also cause harvest problems in cabbage. It is difficult to control because its seeds are long-lived and can germinate from deep in the soil profile. Velvetleaf thrives under high temperatures and seeds germinate throughout the summer.

Smartweeds (*Polygonum* spp.) are prolific seed producers that cause more severe problems on muck soils. The smartweeds are late-season germinators so they escape most herbicide applications and can cause harvest problems. On the positive side, the nectar of the flowers attracts beneficial insects.

Wild Mustard (*Brassica kaber*) is difficult to control because it is in the same plant family as cabbage and therefore the selection of herbicides for control is limited. Like the other broadleaf weeds, it too is a prolific seed producer. Wild mustard is a cool season weed and because of its close relationship to cabbage, can serve as an alternate host for many plant diseases.

Ragweed (*Ambrosia artemisiifolia*) is an allergen and causes harvest problems in cabbage. There are few herbicides available that will control ragweed in cabbage.

Annual grasses also pose a problem in the production of cole crops because of their vigorous growth and ability to produce copious amounts of seed. They are also very tolerant of moisture and temperature extremes once they become established. If uncontrolled, grass weeds can root and branch from the lower joints and stems. Control all annual grasses before they set seed. Some of the most problematic grasses in cole crops are the foxtails (*Setaria spp.*). Foxtails germinate in the early spring and throughout the growing season. They have a very rapid life cycle, with an average of 37 days from seedling to 25% flowering. The seeds can remain viable in the soil for up to 5-10 years. Pre-emergent herbicide applications can effectively control annual grasses for 60-70 days. Field histories are important in annual grass weed management programs so growers know which species are located where in the field.

Foxtails: green (*Setaria viridis*), yellow (*S. lutescens*), and giant (*S. faberi*). Herbicides control all foxtails fairly well despite their being prolific seed producers that can produce 3-5 years of seed in a single season.

Wild Proso Millet (*Panicum miliaceum*) is tougher to control than the foxtails as pre-emergent herbicides are not as effective. Post emergent herbicides provide better control.

Barnyardgrass (*Echinochloa crusgalli*) is a late season germinator that germinates after the pre-emergent herbicides have lost their efficacy. Most of the herbicides registered for the control of barnyardgrass are very effective when

applied post emergence.

Fall Panicum (*Panicum dichotomiflorum*) is another late season germinator that is not affected by pre-emergent herbicides. Fall panicum is more difficult to control than barnyardgrass but some post emergent herbicides provide some control.

Chemical Controls for Weeds in IPM and Resistance Management Programs

Pre-emergence Herbicides

Clomazone (Command 4EC) Command has a 24C label for use on cabbage in Wisconsin to control annual grasses and broadleaves. Before using this product for cabbage, growers must sign a waiver of liability and an indemnification certificate each season. It is used at a rate of 0.25-0.50 lb a.i./A on cabbage no less than 45 days until harvest. A single application is made before planting. Fifty-eight percent of the processed cabbage acres were treated with Command in 1996. Because of issues with revolitilization, Command can not be use within 1200 feet of towns, housing developments, greenhouses, or nurseries.

Dacthal (DCPA) is applied immediately after seeding or transplanting. It is not effective on heavy muck soils or other high organic soils.

Napropamide (Devrinol 50-DF) is used to control annual grasses and broadleaves. It is applied at a rate of 1 lb a.i./A up to the day of harvest. It should be shallowly incorporated after transplanting and irrigated within 24 hours. It is not recommended for use on soils with more than 10% organic matter. Napropamide was used on 75% of the cabbage acreage in 1996.

Trifluralin (Treflan) is used for control of annual broadleaves and grasses at a rate of 0.5-1.0 lb a.i./A up until the day of harvest. It is applied and incorporated before transplant and should not be applied on soils with more than 10% organic matter. Treflan is used on 93% of the fresh market cabbage and 78% of the kraut cabbage in Wisconsin. If this herbicide were lost, there would be no suitable replacements.

Oxyfluorfen (Goal) is annual broadleaf herbicide used at a rate of 0.25-0.5 lb a.i./A up until the day of harvest. It is applied after final tillage but before transplanting the crop. For wider spectrum weed control, Goal may be used following preplant incorporated Treflan. Growers should not use goal in combination with Dual as crop injury can occur. Goal is applied to 10% of the Wisconsin cabbage.

Metolachlor (Dual 8E) has had a 24C label for processing cabbage grown in Wisconsin in recent years for the control of annual grasses, some broadleaf weeds, and yellow nutsedge. It is applied at a rate of 1¼ - 3 pints product/A as a surface broadcast application within 48 hours of transplanting. Sixty-eight percent of the processed cabbage acreage is treated with Dual. It is absolutely necessary to have this herbicide for economical cabbage production in Wisconsin.

Bensulide (Prefar) is applied prior to planting cabbage and is incorporated 1-2 inches into the soil. It may also be applied after seeding but before the crop emerges.

Post emergence Herbicides

Sethoxydim (Poast) is applied as a postemergence spray for annual grass weeds. It is applied at a rate of 0.19-0.28 lb a.

i./A to actively growing grasses no less than 30 days before harvest. Fifty percent of Wisconsin cabbage is treated with Poast.

Clethodim (Select) is an essential post emergence herbicide for escaped annual grass weeds.

Non-selective Herbicides

Paraquat (Gramoxone Extra) is applied post emergence to weed seed germination as a spot treatment before the crop has been planted.

Glyphosate (Roundup) is applied to emerged weeds prior to planting in either the fall before or early spring. It is also used as a wick application in the crop.

Diseases

Alternaria leaf spot (*Alternaria brassicae*) is a destructive disease, particularly in seedbeds. The disease is frequently seed-borne beneath the seed coat and thus is spread with seed to new fields. *Alternaria* overwinters in susceptible weeds or perennial crops. Early symptoms appear immediately after germination as a minute dark spot on the seedling stem, which causes damping-off or stunting of the seedling. Plants affected later in their development show spotting of the heads. These spots vary in size from pinpoints to 2-3 inches in diameter, and are common on old, lower leaves. The lesions begin as small circular yellow areas, which enlarge concentrically and become a black, sooty color. Humidity and temperature play a role in disease frequency and intensity and fungicides only have a suppressive effect on the disease.

Blackleg (*Phoma lingam*) Blackleg can be a very destructive disease of crucifers and can destroy an entire field if left unchecked, but has become less important since effective control measures are now generally applied. This is a very aggressive disease and can cause 100% crop failure in some years. Fungicides aren't the primary control measure; cultural controls are more important. The fungus overwinters on crop debris, or infected seed. Conidia exude from fruiting structures and spread to susceptible plants by splashing rain, irrigation, or wind. All plant parts are susceptible at any stage of plant development with the initial infection often occurring in the planting bed starts on occasional plants. Early symptoms appear on the stem near the soil line as elongated, sunken, tan lesions. The leaf spots are inconspicuous and indefinite at first but later often develop purplish margins. Gradually, the lesions become well-defined and circular with ashen-gray centers in which large numbers of black dots much smaller than a pinhead are scattered irregularly. As the disease progresses, lesions girdle the stem, resulting in the wilting and death of the plant. Roots may also become infected and destroy entire root systems. Above-ground symptoms of root infections are evident by sudden wilting. Wilting caused by blackleg can be distinguished from that caused by *Fusarium* or black rot in that the leaves remain on the plant in the former. Some plants may topple over as they mature because of poor root anchorage.

Black rot *(Xanthomonas campestris* pv. *campestris*) can be a serious disease of cole crops and is considered one of the primary, significant pests. The losses from this disease can be high in years when rainfall is plentiful or dews are heavy and average temperatures range between 60-70°F. Black rot lesions can also provide an entry site for soft rot bacteria.

The bacteria that causes black rot survives from one season to the next on diseased plant debris and in seed. Plants can be infected by the black rot bacteria at any stage in of development. The initial infection occurs most often through the hydathodes or water pores located along the leaf margins. Droplets of water exuded from these pores overnight are later retracted into the plant taking any bacteria that have come into contact with them into the plant as well. Once inside the

plant, the bacteria move downward through the xylem to the stem and roots. Black rot is primarily a disease of the above-ground plant parts. The first signs of the disease appear at the margins of leaves where infections most often occur. A V-shaped area of infected tissue turns yellow with the base of the V toward the midrib. The veins within this chlorotic area become dark in color when the lesion is held before a source of bright light. This vascular discoloration often extends from the leaves to the main stem. As the disease progresses, the V-shaped areas soon die and become tan and dry. Black rot is controlled through hot water seed treatment to kill the pathogen but this can also reduce the germination rate.

Cabbage yellows (*Fusarium oxysporum* f.sp. *conglutinans*) Cabbage yellows affects most cole crops but is especially serious on cabbage. In Wisconsin, yellows was one of the greatest hazards until resistant varieties were developed. The use of resistant varieties is the only way to successfully control this disease. In heavily infested soils it is not uncommon for susceptible varieties to be completely destroyed. The *Fusarium* fungus overwinters on infected plant debris and may persist in the soil without debris for many years. After *Fusarium* becomes established in a locality, it spreads rapidly by means of soil particles moved from one place to another. The fungus enters the plant through wounds or secondary roots. Once inside the plant, the fungus moves into the xylem vessels and from there moves upward into the leaves and stem. Discoloration of infected vessels occurs in advance of the actual fungus and arises from a toxin produced by the fungus. Yellows affects plants at any stage. The first sign of the disease is the lifeless, yellow-green color of the foliage. Most often, foliar discoloration is more intense on one side of the leaf or plant, causing a lateral warping or curling of the leaves and stem. The lower leaves are affected first with symptoms progressing upward. As the affected tissue ages, it becomes brown and brittle. Affected leaves drop prematurely and normal growth is distinctly retarded.

Clubroot (*Plasmodiophora brassicae*) Losses due to clubroot are sometimes extensive, and the economic importance of this disease is increased by the fact that once soil has become infested it remains so for an indefinite period even in the absence of susceptible hosts. Infection occurs through the root hairs and wounds. As the root enlarges, the fungus produces spores that contaminate the soil. Infected root cells expand and later divide into thick-walled, resting spores. As infected tissue matures and decays, spores are released to contaminate soils for 20 years or more. Infested soil is moved to clean fields by equipment, human activity, and running water. The most noticeable symptom of clubroot is the abnormal enlargement of the roots. These enlargements may occur on the very small roots, secondary roots, taproot or underground stem. The root clubs are often thickest at the center, tapering toward either end. Plants with clubbed roots are stunted and leaves may yellow or wilt. However, the disease may progress to a considerable extent before the above-ground symptoms of plant stunting and wilt are noticeable.

Downy Mildew (*Peronospora parasitica*) is a cool weather disease of cole crops that occasionally causes appreciable damage in early or late season crops. Secondary infections by soft rot can result from lesions caused by downy mildew. The fungus survives as mycelium between crops within a single growing season and overwinters as thick-walled oospores in plant residue. The following spring, these resting spores germinate and produce infective spores called conidia. The conidia that are produced on growing plants are carried for long distances in cool, moist air. The mycelium arising from germinating conidia enters plant tissue through stomata.

Plants can be infected at any stage of their development but young plant tissue is more susceptible than old. The white, fluffy mildew develops primarily on the lower leaf surface of cotyledons and the first true leaves. Later, yellow-brown spots with a somewhat scorched appearance develop on the upper leaf surface while a white fluffy growth occurs on the undersides of leaves. Young leaves may yellow and drop while older leaves turn tan and leathery. When the disease is severe, the entire leaf dies. The fungus may cause numerous sunken black spots, varying in size from small dots to an inch or more in diameter on the head.

Wire stem (*Rhizoctonia solani*) attacks cole crops at various developmental stages and causes a wide variety of symptoms depending upon its stage of maturity. The fungus favors young, succulent tissue and dormant storage tissue. Infection occurs when environmental conditions are unfavorable for plant growth or through wounds. The fungus may

enter the plant through natural openings or wounds as well as directly through intact tissue. In young plants grown in cold, wet soils, the fungus usually attacks at the soil line. The tissue becomes water-soaked, rapidly collapses and dies. Affected seedlings never outgrow infection and remain stunted or die outright. Older plants have a greater resistance to infection. At later stages, infected plants turn brownish-black just above the soil line. The stems are somewhat smaller than normal, but are tough and woody. Affected plants may recover and grow normally, but under some conditions, the fungus may continue to retard plant growth.

Fungicide Use in IPM & Resistance Management Programs

Chlorothalonil (Bravo) is a broad-spectrum, non-systemic, protectant fungicide that provides good control of *Alternaria* leaf spot and downy mildew at a rate of 1.5 pt/A when applied at 7-10 day intervals up until 7 days before harvest. It's expensive but there is only a small risk of resistance development.

Maneb (Maneb, Maneb plus zinc, & Manex) is a broad-spectrum, non-systemic, protectant fungicide that provides good control *Alternaria* leaf spot and downy mildew with little risk of resistance. It is applied at a rate of either 1.5-2.0 lb a.i/a or 1.2-1.6 qt a.i./a when symptoms first appear and continued every 7 days until one week before harvest. Because it's less expensive than chlorthalonil, many growers prefer to use this fungicide.

PCNB (Terraclor, Blocker) provides fair to good control clubroot and good control of wire stem. For clubroot it is applied at a rate of 2-6 lb Terraclor 75% WP/100 gallons of transplant water for a rate of 0.5-0.75 pt/plant mix. For wire stem it is used at a rate of 15-20 lb Terraclor 75% WP/50 gal water per acre or 1 level tablespoon/gal water/50 sq ft of seed bed. It is applied to seedbeds as a broadcast drench.

Critical Pest Control Issues

Better broadleaf herbicides are needed to control escaped weed and to provide season-long weed control.
Pyrethroid insecticides must remain available for resistance management programs and as replacements for organophosphates.
IR-4 funding is necessary to look at the efficacy of new fungicides and herbicides for cabbage.
Resistance to existing lepidopteran-control insecticides (pyrethroids, organophosphates, carbamates) is becoming increasingly widespread particularly in the case of the diamondback moth. Control failures were detected in the most recently registered pyrethroid (Warrior) in 1998. Bt-resistance is present in southern production regions although not yet detected in Wisconsin. Resistance in cabbage looper and imported cabbageworm have not yet been detected but past experience with organochlorines (extensive resistance after 10 years) indicates that pyrethroid, organophosphate, and carbamate resistance should be anticipated. New alternative chemistries are of critical importance to establish resistance management programs.

Crop and Pest Timeline																				
April			**May**			**June**			**July**			**August**			**September**			**October**		
early	mid	late	early	mid	late	early	mid	late	early	mid	late	early	mid	late	early	mid	late	early	mid	late
Seedbed Planting																				
		Field Planting																		
						Hand Hoeing														
Scouting																				

									Harvest											
		Cabbage			**Maggot**															
	Flea Beetles																			
		Diamondback					**Moth**													
							Imported Cabbageworm													
										Cabbage Looper										
										Cabbage Aphid										
										Onion Thrips										
	Alternaria																			
					Black Rot															
					Black Leg															
							Club Root													
			Downy									**Mildew**								
							Wirestem													
Cabbage Yellows																				
Damping Off														**White Mold**						
Annual Broadleaf and Annual Grass Weed Control																				
	= present at this time																			
	= treatment period																			

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