PEST MANAGEMENT IN THE FUTURE

A Strategic Plan for the Minnesota and Wisconsin Cabbage Industry

Workshop Summary
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TABLE OF CONTENTS

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ABOUT THE WORKSHOP

A group of growers, processors and technical experts met in Madison, Wisconsin for one and a half days to determine and summarize critical needs for the Minnesota and Wisconsin cabbage industry in terms of efficacy of currently used pest management practices, available tools and alternatives. The group discussed issues pertaining to insects, diseases and weeds and the most critical research, regulatory and educational needs were determined for these pests. The cabbage pest-management strategic plan (PMSP) also builds upon the Cabbage Crop Profiles recently developed for each state, and reflects the next step in the USDA's Office of Pest Management Policy (OPMP) plan to prioritize issues regarding crop production and pest management. This PMSP was developed by growers, food processors, a crop consultant and land-grant extension specialists, in collaboration with the EPA, USDA and the North Central Pest Management Center, Michigan State University.

TOP PRIORITIES FOR MINNESOTA AND WISCONSIN CABBAGE PRODUCTION

Research:

- Better broadleaf herbicides that allow control of escape weeds or better season long control
- IR-4 funding to this region to look at efficacy of new products
- Establish a pest alert monitoring system for loopers and other insect pests
- Establish/refine/implement action thresholds for the lepidoptera complex
- Refine herbicide application equipment, looking at crop safety
- Biological control of insect and disease pests
- Re-establish a variety screening process for diseases, insects and herbicides
- Bio-assays for resistance in diamondback moth and cabbage looper
- Bio-assays for parasitism for diamondback moth and imported cabbage worm

Regulatory:

- Command 3ME and Dual label need full labels (Command can't be used in MN currently and Dual (currently a 24(c) in WI) doesn't have a federal label)
- Need to keep pyrethroid insecticides available for resistance management programs, and as organophosphate replacements
- Need SpinTor greenhouse label for plugs and transplants for diamondback moth management
- Register new chemistries as they become available especially for cabbage maggot, flea beetle and aphid with new seed and soil treatment options

Education:

- Marketing program for fresh market cabbage to increase marketability, create more awareness
- Collaboration and cooperation between states on educational materials
- Improve information database and delivery to growers
- Training on the use of reduced-risk pesticides, i.e., timing, applications methods, etc
- Field demonstration plots on new pesticides for organophosphate, carbamate and pyrethroid replacements
- Implement action thresholds for lepidopteran complex
- White mold identification and control
- Educate growers on biological control of insect and disease pests

BACKGROUND

Wisconsin growers planted approximately 4500 acres of cabbage destined for fresh-market along with 3700 acres planted for kraut in 2001, while Minnesota growers planted approximately 450 acres of cabbage, all of which was destined for fresh-market (USDA NASS). The cabbage crop in Wisconsin and Minnesota is valued at $9.6 million ($5.8 million: fresh market, $3.8 million: kraut) and $0.9 million, respectively. Cabbage is produced primarily in Southeastern Wisconsin and in the Fox River Valley of east-central Wisconsin and around the Twin Cities of Minneapolis and St. Paul, Minnesota.

Production/Cultural Practices: Cabbage is a cool season crop that may be planted early or late in the growing season. The best quality cabbage is produced with daytime temperatures of 70-80º F, sunny conditions, and moist, fertile, well-drained soil. Cabbage can be either direct-seeded via mechanical methods or transplanted by hand. Commercial processors favor transplanting while some fresh market growers choose to direct seed, or use a combination of direct seeded and transplanted cabbage. Cabbage needs at least one inch of rainfall or irrigation water each week. Irrigation ground pipe, when used, is typically placed in the field early in the season and left until after harvest, minimizing worker chemical exposure. Cabbage generally requires 120-150 pounds of nitrogen, 50-150 pounds of phosphorous, and 120-250 pounds of potassium per acre with the addition of phosphorous and potassium based on soil tests. Cole crops often show deficiencies in calcium and boron and can require manganese, magnesium, and molybdenum. Foliar tissue tests can be performed to determine nutrient levels throughout the growing season. Fresh market cabbage fields are typically cultivated once, until rows become too narrow to move equipment through. Hand hoeing is another method of weed control often employed by fresh market growers and typically takes place 6-10 weeks after planting. Commercial processors often forgo cultivation and hand hoeing, instead relying on herbicides for weed control. Scouting for pests takes place throughout the growing season, typically once per week. Fields are inspected for insects, weeds and diseases and appropriate actions are taken based upon the results of scouting. Fresh market cabbage is harvested by hand in Minnesota while approximately half the fresh market acreage and all the processing cabbage is mechanically harvested in Wisconsin. Overall, 80-90% of cabbage acreage in Minnesota and Wisconsin is mechanically harvested.

In most years, insect pests are usually the most damaging and difficult to control in Minnesota and Wisconsin cabbage. The most important insect pests include: cabbage looper, imported cabbageworm, diamondback moth, cabbage maggot and flea beetles. With high parasitism rates of diamondback moth (typically 80-100%, Rice-Mahr et al. 1993), and in the absence of insecticide resistance in this pest, cabbage looper is often the most common and most difficult insect pest to control. Black rot is probably the most damaging disease problem, but like most diseases of crucifers, few therapeutic treatments are available. Many broadleaf and grass weed species are potentially very damaging. However, in tandem with timely cultivation, most weeds are still controlled well with currently labeled herbicides.

Despite the relatively low acreage of cabbage in these states, the high value of the crop (ca. $2,000-4,000/ac), and traditionally high insecticide use of about 5-7 sprays/season, continues to create a demand for effective integrated pest management (IPM) programs.

Integrated Pest Management (IPM): The severity of damage caused by insect, pathogen and weed pests, combined with the high value of the crop, creates several IPM challenges. As with many vegetable crops, the high value of fresh market and processing cabbage often leads to a risk-averse approach to pest control, and subsequently, high pesticide use. However, a recent cabbage IPM demonstration project in Minnesota, using action thresholds, scouting and "reduced-risk" insecticides (SpinTor, Proclaim and Avaunt), with minimal pyrethroid use, provided excellent results for larval pest control. The IPM program, compared with the conventional grower strategy and untreated check, consistently yielded a lower proportion of plants infested with large (late-instar) larvae, and a higher percentage of marketable heads (90-99%) in the 4-year study. The IPM program also resulted in significant reductions in insecticide use (20-66%). The reduction in sprays combined with the increase in marketable heads resulted in increased profits ranging from 3.3-19.8%. Final profit analysis also revealed that the IPM program provided the highest net revenue with the least profit variability (profit risk). These results confirmed the economic benefit of an IPM approach, and indicate that the new reduced-risk insecticides, can provide growers with multiple insect control options, compatible with an IPM approach. With additional research, this IPM program could be combined with weed and pathogen management strategies to create a more integrated crop management (ICM) package for growers. To date, most of the cabbage IPM programs for Minnesota and Wisconsin, continue to rely on timely pest scouting, use of presence/absence action thresholds, and minimum insecticide use to minimize disruption to the naturally occurring parasitoids and other natural enemies attacking the three major lepidopteran pests. Some resistant varieties have been developed for disease control, but very little work has recently been directed toward new cultural or biological control tactics for cabbage IPM.

IPM programs also benefit from having multiple pesticide options, for use, as needed. During the next 5 years, primary concerns related to FQPA, will be insecticide availability for cabbage root maggot, with the potential loss of Diazinon and/or Dyfonate. However, based on recent EPA rulings (2000), Lorsban should still be available for this pest. Finally, Sevin insecticide remains a popular choice by many small-scale growers for flea beetles and other insects, because of its broad-spectrum efficacy and non-restricted use status. Future FQPA review of this carbamate insecticide and its potential loss would create new challenges for many growers.

Insects: The most consistent insect pests of cabbage include the cabbage looper, imported cabbageworm and diamondback moth. Cabbage maggot is typically limited to early season plantings (April-May); thrips can be a major problem, particularly in hot, dry years, or when nearby grain fields are cut in mid-summer, causing thrips to migrate to cabbage.

Insecticide resistance: 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 moth 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 1950's and widespread damage resulted; IPM programs should thus reflect the potential for resistance in all lepidopteran species.

Insect Biological Control: Significant rates of natural parasitism have been reported for the lepidopteran pest complex; diamondback moth is typically most heavily parasitized (80-95%) followed by the imported cabbageworm and the cabbage looper. Since parasitism is a significant mortality factor and resistance to commonly used insecticides is a serious concern, IPM programs which avoid early season broad-spectrum insecticides 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 IPM and Resistance Management programs, cabbage should be scouted weekly and control applications applied only when thresholds are surpassed. Infestation thresholds have been developed for cole crops in both Minnesota and Wisconsin (Rice-Mahr et al. 1993, Hines & Hutchison 2001). Effective IPM programs for this complex should be designed to 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
3. Target early-instar larvae and ensure good plant coverage to improve efficacy.
4. Use pest-specific insecticides early-mid season when diamondback moth and imported cabbageworm are prevalent to conserve natural enemies.

Diseases: With a few exceptions, most of the damaging diseases in cabbage are not treatable with fungicides or bactericides. For example, black rot, caused by a bacterium, can be treated with copper (e.g., Kocide), but only for low-level infestations. Tip burn, a physiological problem, is caused primarily by a lack of water during critical development periods. Thus, growers must rely on crop rotation, clean cultural practices, resistant varieties and timely irrigation (where possible), to help manage most crucifer diseases. The primary materials available for cabbage diseases include Bravo, Maneb, Terraclor and various copper formulations. Where possible, such as Ridomil Gold Bravo for downy mildew control, it is critical that these remain available for selected diseases. When these products come under review, with respect to FQPA, there will be a renewed need to assess risks/benefits.

Weeds: For both broadleaf and grass species, trifluralin (e.g., Treflan) has typically been the most commonly used herbicide on cabbage in Minnesota. To date, we are not aware of weed resistance problems as a result of this use. This is likely due to the fact that it is only used once, at planting, and may not be used significantly on surrounding crops on a given farm. Several options exist to prepare seedbeds for direct seeding or transplanting including cultivation and applications of some herbicides. Command, Treflan can be used for both direct-seeded and transplanted cabbage. However, Treflan and Dacthal are not recommended for use on muck soils. In addition, Goal is not recommended for use on direct-seeded cabbage. Post-emergence herbicides (Poast, Gramoxone and Glyphosate) are typically limited to weed escape situations, in unusually high weed pressure fields. Pyridate (lentagran), another broad-spectrum post-emergence herbicide is no longer manufactured. Potential additional losses of herbicides would limit grower options. If and when these products come under review, with respect to FQPA, there will be a renewed need to assess risks and benefits of each.

Insect Pests

Although quality standards may vary somewhat depending on whether cabbage is being produced for the fresh market or processing, consumers have a low tolerance of insect damage in the foliage or insect excrement within the leaves. Growers may have more options to control insects early in the production that may allow survival of more beneficial insects but as harvest time approaches, the control options are more limited due to the concern about insect damage.

Cabbage Looper (*Trichoplusia ni*)

- Cabbage looper (CL) is major lepidopteran pest in the upper Midwest
- The most tenacious and difficult to control pest of cabbage
- Insect pressure depends on dispersal from the South, most fluctuating pest from year to year based on dispersal
- Plants can be severely defoliated, stunted and susceptible to disease

Organophosphate (OP) insecticides currently registered:

- OPs generally not used due to resistance problems and their poor efficacy on cabbage looper

Naled (Dibrom)

- short PHI but still not used due to resistance problems
- used as a clean up in emergency situation
- efficacy poor
- expensive
- use has been replaced with use of pyrethroids

Carbamate insecticides currently registered:

- Carbamates generally poor on cabbage looper

Carbaryl (Sevin)

- can be effective if timed correctly – when larvae are small
- poor looper control
- not an RUP (good for fresh market and farmers market)
- hard on beneficials and will flare aphids
- 7-14 day PHI

Methomyl (Lannate)

- efficacy fair if timing is correct - when larvae small
- not used much
- if controlling only looper this may be used

Thiodicarb (Larvin)

- short residual
- efficacy fair

Pyrethroid insecticides currently registered: Primary tool along with reduced-risk products

- Need rotation of chemical families for resistance management
- If cabbage looper is originating from a heavily treated area in the South (especially cotton producing areas), pyrethroids may not be effective
- Pyrethroids are hard on natural enemies
- Hard to choose one over another, can all be equally effective (Warrior and Capture have longer residual and may therefore be more useful)
- 10% of plants infected with cabbage looper larvae is the economic threshold

Lambda cyhalothrin (Warrior)

- efficacy good
- expensive for small fresh-market growers

Bifenthrin (Capture)

- efficacy good to excellent

Permethrin (Pounce, Waylay)
- efficacy good to excellent

Cypermethrin (Ammo)
- efficacy good to excellent

Esfenvalerate (Asana)
- efficacy good
- weakest of the pyrethroids

Fenpropathrin (Danitol)
- efficacy good to excellent

Zeta cypermethrin (Fury, Mustang)
- efficacy good

Reduced-Risk pesticides: all expensive

Spinosad (SpinTor)
- efficacy good to excellent
- used in rotation with pyrethroids
- expensive
- label has distinct resistance management criteria
- easy on beneficials

Emamectin benzoate (Proclaim)
- efficacy good
- expensive
- only been registered recently, not a lot of experience using product
- delay in mortality (activity) of insects

Indoxocarb (Avaunt)
- efficacy good
- expensive
- recently registered, not lot of experience using product
- not as good on loopers

Tebufenozide (Confirm)
- efficacy good
- expensive

Bacillus thuringiensis (MVP, Javelin, Dipel)
- timing critical especially with cabbage looper
- efficacy fair to good
- requires multiple applications
- varietal differences in efficacy, depends on plant structure
- short residual
- a few formulations may be used by organic growers

Other insecticides currently registered:

Endosulfan (Thiodan)
- not used much
- efficacy poor to fair
- toxicity is an issue

Other pest management aids:
- early planting dates with locally produced transplants will help reduce resistance problems
- organic growers will select virus infected larvae and blend up for applying to plants (can't be used on a large scale)
- maintain proper plant health to give the crop a competitive edge over pests

Pipeline pest management tools:
- Methoxyfenozide

"To do" list for cabbage looper:

Research needs:
- In-field assay for adult resistance, especially for pyrethroids
- Monitoring for dispersal patterns, forecasting model

- Improve biological control of cabbage looper
- Augmentation of *Trichograma spp.*
- Continued efficacy testing of new products
- Modify/refine action thresholds

Regulatory needs:

- Keep array of products available, cost control plus resistance management
- Cost share for scouting practices

Educational needs:

- Explain mode of action and application timing for some reduced-risk products where insects are not controlled immediately
- Newsletter with data to growers
- Education and efficiency of scouting practices, IPM education
- Need more Extension personnel to help disseminate information to growers

Diamondback Moth (*Plutella xylostella*)

- The diamondback moth (DBM) is an economic pest of cabbage in the upper Midwest
- Adults may survive winters but generally diamondback moth either migrate to the upper Midwest or are shipped in on transplants
- Larval feeding causes deformed heads and encourages soft rot.
- Sporadic issues with resistance
- Biological control is the method of control, not a big problem in MN

Organophosphate (OP) insecticides currently registered:

Chlorpyrifos (Lorsban 50W)

- poor efficacy

Diazinon (Diazinon 50W)

- labeled but not used because of resistance problems since 1970s

Naled (Dibrom)

- short PHI but still not used due to resistance problems
- efficacy poor
- expensive
- use has been replaced with pyrethroids and reduced-risk pesticides

Carbamate insecticides currently registered:

- Generally poor on diamondback moth
- Sporadic resistance from the south

Carbaryl (Sevin)

- can be effective if timed correctly – when larvae are small
- fair DBM control
- not a RUP (good for fresh market growers)
- hard on beneficials and will flare aphids
- 7-14 day PHI

Methomyl (Lannate)

- efficacy fair if timing is correct - when larvae small
- not used much
- resistance issue, spotty

Thiodicarb (Larvin)

- short residual
- efficacy fair
- resistance issue, spotty

Pyrethroid insecticides currently registered: Primary tool along with reduced-risk products

- Need rotation of chemical families for resistance management
- If diamondback moth are coming from heavily treated areas in the South (coming out of transplant beds), pyrethroids are not as effective
- All hard on natural enemies, not an IPM material for diamondback moth
- May cause flare ups of diamondback moth due to resistance
- Hard to choose one over another, all are equally effective (Warrior and Capture have longer residual and may therefore be more useful)

Lambda cyhalothrin (Warrior)

- efficacy good

Bifenthrin (Capture)

- efficacy good to excellent

Permethrin (Pounce, Ambush, Waylay)

- efficacy good to excellent

Cypermethrin (Ammo)

- efficacy good to excellent

Esfenvalerate (Asana)

- efficacy good

Zeta cypermethrin (Fury, Mustang)
- efficacy good

Reduced-Risk pesticides: all expensive

Spinosad (SpinTor)
- a primary control tool for diamondback moth
- efficacy good to excellent
- early season use
- used in rotation with pyrethroids
- expensive
- label has distinct resistance management criteria
- easy on beneficials

Emamectin benzoate (Proclaim)
- efficacy good
- expensive
- only been registered recently, not a lot of experience using product
- delay in mortality (activity) of insects

Indoxocarb (Avaunt)
- efficacy good
- expensive
- recently registered, not a lot of experience using product

Tebufenozide (Confirm)
- efficacy poor
- expensive

Bacillus thuringiensis (MVP, Javelin, Dipel)
- timing critical especially with diamondback moth
- efficacy good
- requires multiple applications (up to 4-6)
- varietal differences in efficacy, depends on plant structure
- short residual
- a few formulations may be used by organic growers

Other insecticides currently registered:

Endosulfan (Thiodan)
- not used much
- efficacy poor to fair
- toxicity an issue

Other pest management aids:
- early planting dates with locally produced transplants will help reduce resistance problems
- keep transplants free from infestation
- overhead irrigation inhibits mating
- 90-95% natural biological control
- pheromone (traps) used as monitoring tool
- isolation from adjacent fields and crop rotation
- maintain proper plant health to give the crop a competitive edge over pests

"To do" list for diamondback moth:

Research needs:
- Develop parasite-diamondback moth thresholds
- Develop assay for parasitization
- Resistance levels of diamondback moth
- Strengthen research on biological control

Regulatory needs:
- Register SpinTor for greenhouse use

Educational needs:
- Educate growers on IPM

- Explain mode of action and application timing for some reduced-risk products where insects are not controlled immediately
- Newsletter with data to growers
- Education and efficiency of scouting practices, IPM education
- Need more Extension personnel to help disseminate information to growers

Imported Cabbageworm (*Pieris rapae*)

- Imported cabbageworm (ICW) is a day-flying butterfly that overwinters in the upper Midwest.
- Feed on outer leaf margins and move inward as they develop
- Contaminate leaves with large amounts of frass
- Has shown resistance to Chlorinated Hydrocarbons in the 60's, concern about resistance developing now to current chemistries
- Can be a problem for fresh market growers in marketing heads (low economic threshold: 0-5% infested)
- Easier insect to kill than cabbage looper or diamondback moth

Organophosphate (OP) insecticides currently registered: OPs generally not used on imported cabbageworm

Diazinon (Diazinon 50W)
- efficacy fair to good

Chlorpyrifos (Lorsban 50W)
- efficacy fair to good

Naled (Dibrom)
- short PHI
- used as a clean-up in emergency situation
- efficacy fair to good
- expensive
- use has been replaced with use of pyrethroids

Carbamate insecticides currently registered:

Carbaryl (Sevin)
- can be effective if timed correctly–when larvae are small
- efficacy fair to good
- not an RUP (good for fresh market growers)
- hard on beneficials and will flare aphids
- 7-14 day PHI

Methomyl (Lannate)
- efficacy fair to good if timing is correct - when larvae small
- not used much

Thiodicarb (Larvin)
- short residual
- efficacy fair to good

Pyrethroid insecticides currently registered: Primary tool along with reduced-risk products

- Need rotation of chemical families for resistance management
- Pyrethroids hard on natural enemies
- Hard to choose one over another, all are equally effective (Warrior and Capture have longer residual and may therefore be more useful)

Lambda cyhalothrin (Warrior)
- efficacy good to excellent

Bifenthrin (Capture)
- efficacy good to excellent

Permethrin (Pounce, Waylay)
- efficacy good to excellent

Cypermethrin (Ammo)
- efficacy good to excellent

Esfenvalerate (Asana)
- efficacy good to excellent

Fenpropathrin (Danitol)
- efficacy good to excellent

Zeta cypermethrin (Fury, Mustang)
- efficacy good to excellent

Reduced-Risk pesticides: all expensive

Spinosad (SpinTor)
- efficacy good to excellent
- used in rotation with pyrethroids
- expensive
- label has distinct resistance management criteria
- easy on beneficials

Emamectin benzoate (Proclaim)
- efficacy good
- expensive
- only been registered recently, not lot of experience using product
- delay in mortality (activity) of insects

Indoxocarb (Avaunt)
- efficacy good to excellent
- expensive
- recently registered, not lot of experience using product

Tebufenozide (Confirm)
- efficacy good to excellent
- expensive

Bacillus thuringiensis (MVP, Javelin, Dipel)
- timing critical especially with imported cabbageworm
- efficacy fair to good to excellent
- requires multiple applications (4-6)
- short residual
- a few formulations may be used by organic growers

Other insecticides currently registered:

Endosulfan (Thiodan)
- not used much
- efficacy good
- toxicity an issue

Other pest management aids:
- maintain proper plant health to give the crop a competitive edge over pests
- rotation from previous cabbage fields
- fall tillage practices and their impact on overwintering

Pipeline pest management tools:
- Methoxyfenozide

"To do" list for imported cabbageworm:

Research needs:
- Predictive model for when generations start
- Overwintering survival bench marks
- Fall tillage practices and their impact on over wintering
- Improved biological control

Regulatory needs:

Educational needs:
- Educate growers on IPM
- Explain mode of action and application timing for some reduced-risk products where insects are not controlled immediately
- Newsletter with data to growers
- Education and efficiency of scouting practices, IPM education
- Need more Extension personnel to help disseminate information to growers

Cabbage Maggot (*Delia radicum*)

- Sporadic pest but can build in local areas where there is minimal rotation and predators absent
- Seedlings more susceptible during wet springs
- 3 generations per year, 1st generation is the most serious and can be predicted
- Over winters in MN and WI in the soil as pupae

Organophosphate (OP) insecticides currently registered:

Chlorpyrifos (Lorsban)

- Primary control used
- Efficacy good
- Applied in furrow or transplant water
- Worker not in direct contact with chemical during mechanical transplanting
- Concern with resistance, no alternatives

Diazinon (Diazinon)

- short lived
- efficacy fair
- not used as much as chlorpyrifos commercially

Other pest management aids:

- heat unit predictor
- crop rotation–distance (1/4 miles)
- later planting dates to avoid pest based on predictive model or phenology (when common purple lilacs are in full bloom)

Pipeline pest management tools:

- fipronil
- neonicotinoids

"To do" list for cabbage maggot:

Research needs:

- Develop OP alternatives such as fipronil and neonicotinoids

Regulatory needs:

- Essential to register OP alternatives

Educational needs:

- Expand delivered use of predictive models via newsletter, etc for both states

Cabbage, Turnip, and Green Peach Aphids (*Brevicoryne brassicae, Lipaphis erysimi, Myzus persicae*)

- Aphid feeding injury can kill seedlings or young transplants while injury to older plants can result in yellow, curled leaves, stunted growth and deformed heads
- WI the cabbage aphid is only pest controlled of these aphids, thresholds are available (Very low thresholds)
- Minnesota: aphids are generally not an issue in southern MN, can be a problem in northern MN
- Wisconsin: cabbage aphid is the only species of concern

Organophosphate (OP) insecticides currently registered:

Diazinon (Diazinon)
- efficacy fair
- hard on beneficials
- inexpensive
- short PHI allows use in fresh market

Dimethoate (Dimethoate 4E)
- efficacy fair to good
- systemic activity
- hard on beneficials
- inexpensive
- PHI is short

Disulfoton (Di-Syston 8)
- efficacy good
- soil application, systemic

Oxydemeton methyl (Metasystox R)
- efficacy good

Other insecticides currently registered:

Imidacloprid (Provado/Admire)
- material of choice
- efficacy good to excellent

M-Pede
- efficacy poor to fair
- used by organic and small growers

Bifenthrin (Capture)
- efficacy good
- hard on natural enemies
- interrupts IPM programs for lepidopteran pests when used early in season

Lambda-cyhalothrin (Warrior)
- efficacy fair
- takes out natural enemies
- interrupts IPM programs for lepidopteran pests when used early in season

Zeta-cypermethrin (Mustang)
- efficacy fair
- takes out natural enemies
- interrupts IPM programs for lepidopteran pests when used early in season

Other pest management aids:
- conserve natural enemies

"To do" list for cabbage aphids:

Research needs:
- Determine thresholds
- Evaluate varietal differences in susceptibility
- Develop products that control cabbage aphid which do not disrupt natural enemies

Regulatory needs:
- Register aphicides which do not disrupt natural enemies

Flea Beetles (*Phyllotreta spp.)* ON DIRECT SEEDED

- Flea beetles are occasional pests which can cause significant damage
- Serious pest of fresh market direct seeded cabbage, need to monitor daily
- Control critical up to 3 leaf stage

Organophosphate (OP) insecticides currently registered:

Chlorpyrifos (Lorsban 50W)
- efficacy good

Disulfoton (Di-syston 8)
- efficacy good
- in furrow treatment

Carbamate insecticides currently registered:

Carbaryl (Sevin)
- efficacy good to excellent
- use early in season

Thiodicarb (Larvin)
- efficacy good
- not used much

Other insecticides currently registered:

Zeta cypermethrin (Mustang)
- efficacy good to excellent
- use early and late to avoid disruption of natural enemies

Bifenthrin (Capture)
- efficacy good to excellent
- use early and late to avoid disruption of natural enemies

Lambda cyhalothrin (Warrior)
- efficacy good

Bifenthrin (Capture)
- efficacy good to excellent

Permethrin (Pounce, Waylay)
- efficacy good to excellent

Cypermethrin (Ammo)
- efficacy good to excellent

Esfenvalerate (Asana)
- efficacy good
- weakest of the pyrethroids

Zeta cypermethrin (Fury, Mustang)
- efficacy good

Imidacloprid (Provado)
- efficacy – no data but should work based on other crops
- potentially a good OP/carbamate alternative

"To do" list for flea beetles:

Research needs:
- Seed treatment efficacy trials
- Using mustards as a trap crop

Regulatory needs:
- Residue data for Cruiser (IR-4)

Thrips (*Thrips tabaci*)

- Thrips are slender, minute insects which are sporadic pests of cabbage in production and storage
- Tend to be more of a problem in hot, dry weather on kraut cabbage
- Extensive damage to the head results in an unmarketable product
- No good controls that won't disrupt IPM programs
- Mid-late season problem
- Late season thrips have developed resistance to pyrethroids

Organophosphate (OP) insecticides currently registered:

Dimethoate (Dimethoate)

- efficacy poor
- not used because of resistance

Other insecticides currently registered:

Lambda cyhalothrin (Warrior)

- efficacy good if applied when thrips enter cabbage

Bifenthrin (Capture)

- efficacy good if applied when thrips enter cabbage

Cypermethrin (Ammo)

- efficacy good if applied when thrips enter cabbage

Zeta cypermethrin (Fury)

- efficacy good if applied when thrips enter cabbage

Spinosad (SpinTor)

Other pest management aids:

- varieties
- avoid planting cabbage next to a small grain fields and/or alfalfa, if possible

Pipeline pest management tools:

- Fipronil

"To do" list for thrips:

Research needs:

- Varietal resistance studies for our region (MN and WI)
- Improved scouting
- SpinTor efficacy on cabbage

Fungal/Bacterial Pathogens:

Alternaria leaf spot (*Alternaria brassicae*)

- Overwinters in susceptible weeds or perennial crops, frequently seed-born
- Foliar problem, early symptoms appear immediately after germination as a minute dark spot on stem
- Sporadic problem but when it does occur it can be a significant problem, more of a problem in Northern MN
- Humidity and temperature are factors in occurrence
- Fungicides only suppress the disease

Fungicides currently registered:

Maneb (Manex/Maneb)

- efficacy good
- very small resistance risk
- protectant, non-systemic
- PHI = 7 days

Chlorothalonil (Bravo)

- efficacy good
- expensive, twice as much as maneb
- very small resistance risk
- protectant, non-systemic
- PHI = 7 days

Other pest management aids:

- crop rotation to non-cruciferous crops
- control weeds for air drainage

"To do" list for alternaria leaf spot:

Research needs:

- Research strobilurins

Regulatory needs:

- IR-4 research and register strobilurins

Educational needs:

- Educate growers on identification of disease in field, colored fact sheets

Black rot *(Xanthomonas campestris* pv. *campestris*)

- Primary significant pest, can take out a whole field
- First appears at the margins of leaves; V-shaped area of infected tissue turns yellow with the base of the V toward the midrib, area becomes dark in color
- Importance of seed and transplant transmission–moves into production area from seed and transplant
- Some varieties in fresh market are resistant, few kraut varieties are tolerant
- Hot water seed treatment will destroy the pathogen affecting the seed but can also reduce the germination rate
- Bacteria are systemic in the seed

Bactericides currently registered:

Copper (Kocide DF)

- efficacy poor
- can lead to speckling of leaves, especially in hot weather

Other pest management aids:

- 3-4 year crop rotations to non-cruciferous crops
- plant disease resistant varieties
- hot water seed treatment
- no crop activity (moving irrigation pipe, weeding and cultivation) when plants are wet
- harvest or disk fields that are infected

Pipeline pest management tools:

"To do" list for black rot:

Research needs:

- Improve handling or treatment of seed
- Screen new seed treatments

Regulatory needs:

- Improved pathogen detection/identification for use in seed and transplant certification

Blackleg (*Phoma lingam*)

- Primary significant pest, can take out an entire field
- Blackleg overwinters on crop debris, or infected seed
- Early symptoms appear as elongated, sunken, tan lesions; some plants may topple as they mature because of poor root anchorage
- Importance of seed and transplant transmission – moves into production area from seed and transplant
- Hot water seed treatment will destroy the pathogen on and in the seed but can also reduce the germination of the seed
- Have lost the benomyl treatment used previously
- Aggressive disease and hard to stop, potential 100% crop loss
- Fungicides are not generally recommended to control, cultural control is more important

Other pest management aids:

- 3-4 year crop rotations to non-cruciferous crops
- hot water seed treatment

Pipeline pest management tools:

- strobilurins as a seed treatment and foliar spray

"To do" list for blackleg:

Research needs:

- Test thiophanate-methyl as a benomyl replacement
- Continue to evaluate germplasm for possible resistance

Regulatory needs:

- Seed certification and testing

Educational needs:

- Educate growers on management

Clubroot (*Plasmodiophora brassicae*)

- Causes abnormal enlargement of roots
- Affected plants may be stunted and have yellow, wilted leaves
- SE WI: can be a very serious problem, once in field it can be there for 20-30 years. Not a problem in other areas, not often seen by growers
- Can be brought into a production area on transplants
- Soil born on transplants
- Other crucifer plants can be alternate hosts

Fungicides currently registered:

Pentacloronitrobenzene (Terraclor, Blocker)

- efficacy fair to good and variable
- put in transplant water, treat a band in soil

Other pest management aids:

- plant disease free transplants
- plug plants would be a plus, not bringing in soil
- 7 year rotation: rotate to non-cruciferous crops
- raise soil seedbed pH to 7.2-7.5, difficult to do especially if rotating cabbage with a low pH crop such as potato.

Pipeline pest management tools:

Fluazinam (Omega)

- registered for use in potato
- used in Europe

"To do" list for clubroot:

Research needs:

- Continue to screen germplasm for resistance
- Efficacy data for Omega (IR-4)
- Improve diagnostic assay method for pathogen in soil and seed bed
- Resistant cultivars

Regulatory needs:

- Transplant certification and testing

Educational needs:

- Identification aids, include all diseases (web site)

Downy Mildew (*Peronospora parasitica*)

- Occasional pest
- White, fluffy mildew develops primarily on the lower leaf surface
- Problem on transplants brought in, not a problem with plugs
- Cool and wet conditions

Fungicides currently registered:

Chlorothalonil (Bravo) & mefenoxam + chlorothalonil (Ridomil Gold Bravo)

- efficacy good
- expensive**,** limits use

Fosetyl-Aluminum (Aliette)

- expensive
- never/rarely recommended

Maneb

- efficacy good
- cost effective
- direct sprays early in season if needed

Other pest management aids:

- crop rotation: 2-3 years
- plant disease free transplants

Pipeline pest management tools:

- several possible materials currently labeled on potato for late blight control: cymoxanil (Curzate), dimethomorph (Acrobat), Zoxamide (Gavel), Propamocarb hydrochloride (Previcur Flex)
- famoxate + cymoxamil (Tanos)—in pipeline for potato label

"To do" list for downy mildew:

Research needs:

- Evaluate products used on other crops, see pipeline tools, breeding for resistance

Regulatory needs:

- Disease free transplant production and certification process

Educational needs:

- Identification aids, include all diseases (web site)

Wirestem (*Rhizoctonia solani*)

- Not a significant problem but fairly common; widespread in WI
- Attacks cole crops at various developmental stages and causes a wide variety of symptoms depending upon its stage of maturity
- May enter the plant through natural openings or wounds as well as directly through intact tissue; affected plants may recover and grow normally, but under some conditions, the fungus may continue to retard plant growth.
- Problem in transplants brought in or in greenhouses using too much water.

Fungicides currently registered:

Pentacloronitrobenzene (Terraclor, Blocker)

- efficacy good
- seed bed broadcast drench, or transplant water aimed at club root would also control wirestem

Other pest management aids:

- raise seedlings in beds that are disinfected by steam or chemical fumigants
- rotation

Pipeline pest management tools:

- strobilurins, Cabrio and Quadris

"To do" list for wirestem:

Research needs:

- Data for strobilurins, develop resistance management strategy if strobilurins used

Regulatory needs:

- Register strobilurins if effective

Educational needs:

- Fact sheets, breeding for host resistance

Cabbage yellows (*Fusarium oxysporum* f.sp. *conglutinans*)

- Can affect plants at any stage; the first sign of the disease is the lifeless, yellow-green color of the foliage
- As affected tissue ages, becomes brown and brittle, eventually drops
- Potentially a major problem if resistant varieties weren't available
- Resistant varieties critical (was a major problem in 1920's)

Other pest management aids:

- plant resistant varieties; many available

"To do" list for yellows:

Research needs:

- Varietal screening MUST continue; all new cultivars must have resistance to yellows pathogen

Educational needs:

- Companies provide information for varietal resistance

White Mold (*Sclerotinia sclerotiorum*)

- Becoming more wide spread especially from soybean, sunflower and snap bean rotations
- Innoculum is problem, cabbage is creating own micro-environment
- Significant problem
- Once cabbage is infected can't use a fungicide to control

Biological control:

- somewhat effective on snap beans and dry beans, Intercept WG contains a fungus that attacks and rots white mold; would be applied as part of an IPM program
- Apply Intercept WG in the fall prior to tillage and then incorporate; two fungi in contact and by spring the sclerotia of *S. sclerotiorum* are decaying

"To do" list for white mold:

Research needs:

- Management of white mold
- Look for additional biocontrols

Educational needs:

- Educate growers on symptoms and control
- Tillage and management of white mold
- Better understanding of conditions that favor biocontrols
- Improved fungicide selectivity
- Better disease forecasting tools—decision support for growers

Damping-Off Diseases

Maintain the broad spectrum seed protectants.

OVERALL: Thiram as a seed protectant is an important issue. If registration is lost, need replacements for a broad spectrum fungicide to prevent seed and seedling infection of damping-off fungi

Bacterial Soft Rot

Not a commercial problem. Need to control wounds to cabbage from other sources.

Weeds:

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

Before planting, perennial weed populations should be reduced or eliminated. In most cases early season cole crops mature before annual weeds become a problem. However, winter annual weeds, particularly those belonging to the mustard family, should be controlled prior to planting. Early in the season, cultivation should be used 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 herbicides are often used if weeds exceed threshold levels. Cabbage has an open canopy allowing many weed species to flourish.

Annual Broadleaf Weeds

Lambsquarters (*Chenopodium album*)
- Occupies all growing areas of cabbage, great seed producers–large seed bank
- Germinates throughout the growing season
- Enough escapes to replenish seed source
- No resistance shown to cabbage herbicides at this time
- Treat during early season through germination

Pigweed spp (*Amaranthus retroflexus*) Waterhemp, Redroot, Prostrate
- Occupies all cabbage growing areas, great seed producers–large seed bank
- Germinates throughout the growing season
- Enough escapes to replenish seed source
- No resistance shown to cabbage herbicides at this time
- Treat during early season–germinating
- Have seen resistance
- Waterhemp is tougher to kill

Velvetleaf (*Abutilon theophrasti*)
- Tolerance to herbicide programs
- Late season germinator
- Germinates deep in soil, therefore may escape herbicides
- Causes harvest problems
- Can cause problems with white mold and diseases, umbrella affect
- Creates high humidity in canopy

Smartweed (*Polygonum spp.*)
- Prolific seed producer
- More of a problem on high organic soils
- Harvest problems
- Late season germinator so may escape herbicides
- Nectar off flowers is good for parasites

Wild Mustard (*Brassica kaber*)
- Same family as cabbage, limited herbicide selection
- Prolific seed producer
- Disease alternative host
- Primarily a cool season weed

Ragweed (*Ambrosia artemisiifolia*)

- Prolific seed producer
- Stiff stem
- Harvest problem
- Limited herbicide selection
- Allergen

*See table for others

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. All annual grasses should be controlled 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. Two key points regarding grasses:

1. Pre-emergent applications to the weed. Can control effectively for 60-70 days.
2. Field histories are important to know what weeds are present.

Foxtails: Green, Yellow and Giant

- Herbicides are fairly good
- Prolific seed producers, 3-5 years of seed

Wild Proso Millet

- Prolific seed producers
- Tougher to control than foxtails
- Pre emergence herbicides not as effective, post emergence herbicides work better

Barnyard grass

- Late season germinator coming in behind the pre-emergent herbicides
- Herbicides are fairly good
- Prolific seed producer, 3-5 years of seed
- Post applications work well

Fall panicum

- Late season germinator coming in behind the per-emergent herbicides
- Harder to control pre-emergent than barnyard grass
- Post applications work well
- Post grass herbicides have known resistance especially with crabgrass, green foxtail

Perennial weeds

Roundup has to this point controlled perennial weed problems effectively

Yellow nutsedge

- Dual is controlling effectively

Wirestem muhly

- Can manage outside the crop

Emerging weed problems:
Waterhemp
- Becoming a bigger problem in other crops

Mustards
Wooly cupgrass
Research needs:
- Control issues: rates, application techniques, timing
- Resource use patterns, document field history
- Affects on yield and weeds as host sites for insects (including beneficial insects) and diseases
- Remote imagery, site specific applications
- Understand weed biology, competition between species, interference of weed species

Education needs:
- Identification of weeds and seedlings
- Application of knowledge to cabbage
- Documenting field history for control selection

Chemical controls currently registered

Pre-emergence:
Clomazone (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; 58% of processed cabbage acres treated with Command in 1996.
- this product is absolutely needed
- can't be used within 1200 feet of towns, housing developments, greenhouses and nurseries

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

Napropamide (Devrinol) 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 applied and shallowly incorporated after transplanting and irrigated within 24 hours and 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 annual grasses. It is used at a rate of 0.5-1.0 lb a.i./A up until the day of planting. It is applied and incorporated before transplanting 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.
- absolutely needed

Oxyfluorfen (Goal) is used to control annual broadleaves. It is used at a rate of 0.25-0.5 lb a.i./A up until the day of planting. It is applied after final tillage but before transplanting. For wider spectrum weed control, Goal may be used following preplant incorporated Treflan. Goal should not be used in combination with Dual as crop injury can occur. Ten percent of the Wisconsin cabbage acreage was treated with Goal.
- essential to some growers–have to use transplants

Metolachlor (Dual) is absolutely needed

Bensulide (Prefar) is applied prior to planting and incorporated into soil 1-2 inches. Can also be applied after seeding and prior to crop emergence, but should be irrigated within 24 hours of application.

Post-emergence:
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. Poast is applied to 50% of the cabbage acreage in Wisconsin.

- essential for escape grasses

Clethodim (Select)

- essential for escape grasses

Non Selective:
Paraquat (Gramoxone Extra): some formulations allow for spot applications in cabbage—check label. Apply to emerged weeds prior to seeding or transplanting, or after seeding but prior to emergence.

Glyphosate (Roundup) is applied to emerged weeds prior to planting in either the fall or spring. Applied at 0.75-1.1 lb acid equivalent/A.

- essential as a wick application

Annual broadleaves:
Other pest management aids:

- Cultivation: 2-3 times for fresh market, 1-2 times for processing
- Companion crops
- Hand hoeing (twice max.) is very expensive
- Sanitation of equipment so as not to spread weed seeds
- Use of plastic mulch and other mulches

Pipeline pest management tools:

- Sulfentrazone (Authority) on nightshade, waterhemp in some situations

"To do" list for weeds:
Research needs:

- Develop a Liberty Link cabbage
- Companion crops
- Carfentrazone (Aim) as a burndown
- Shielded application techniques
- Flame burners
- Beet thinner
- Site specific identification–detect spray
- Weed shifts and resistance
- Lack of post emergent annual broadleaf herbicides–research new herbicides

Regulatory needs:

- Lack of post emergent annual broadleaf herbicides – register new herbicides

Educational needs:

- Weed identification and weed biology

Annual grasses:
Other pest management aids:

- Cultivation: 2-3 times for fresh market, 1-2 times for processing
- Companion crops
- Hand hoeing (twice max.) is very expensive
- Sanitation of equipment so as not to spread weed seeds
- Use of plastic mulch and other mulches

Pipeline pest management tools:

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"To do" list for weeds:

Research needs:

- Develop a Liberty Link cabbage
- Companion crops
- Carfentrazone (Aim) as a burndown
- Flame burners
- Beet thinner
- Site specific identification – detect spray
- Weed shifts and resistance, look at other compounds

Regulatory needs:

Educational needs:

- Weed identification and weed biology
- Proper use of post emergent applications to delay resistance

Production Issues:

- Compaction an issue with herbicide injury, especially trifluralin and clomazone
- Sequence of tillage and how you prepare the seed bed.

Table 1. Registered Pesticides for Cabbage in Minnesota and Wisconsin

Active Ingredient	Trade Name	Manufacturer
Insecticides		
Diazinon	Diazinon	UAP, Gowan, MicroFlow, Helena, Drexel
Chlorpyrifos	Lorsban	Dow, WilburEllis, Gowan
Dimethoate	Dimethoate	UAP, Gowan, MicroFlow, Helena, Drexel
Naled	Dibrom	UAP, Amvac
Carbaryl	Sevin	UAP, Aventis, Gowan, WilburEllis
Methomyl	Lannate	DuPont
Lambda cyhalothrin	Warrior	Syngenta
Bifenthrin	Capture	FMC
Permethrin	Pounce, Ambush, Waylay	FMC
Cypermethrin	Ammo	UAP, FMC, Helena
Esfenvalerate	Asana	DuPont
Spinosad	SpinTor	Dow
Emamectin benzoate	Proclaim	Syngenta
Indoxocarb	Avaunt	DuPont
Bacillus thuringiensis	MVP, Javelin, Dipel	Valent, Certis
Zeta cypermethrin	Fury, Mustang	FMC
Endosulfan	Thiodan	FMC, Aventis
Imidacloprid	Admire, Provado	Bayer
Tebufenozide	Confirm	Dow
Disulfoton	Di-Syston	Bayer
Oxydemeton methyl	Metasystox	Gowan, Bayer
Soap	M-Pede	Dow
Fenpropathrin	Danitol	Valent
Fungicides		
Chlorothalonil	Bravo, Equus, Echo	Syngenta, Griffin, Sipcam
Maneb	Maneb, Manex	Cerexagri, Bayer Crop Sciences, Griffin
Copper	Kocide	Griffin
Pentacloronitrobenzene	Terraclor	Uniroyal Chemical, Amvac
Fosetyl-aluminum	Aliette	Bayer Crop Sciences
Captan	Captan	MicroFlow, Helena, Drexel, UAP
Thiram	Thiram	UCB Chemicals
Herbicides		
DCPA	Dacthal	Amvac
Napropamide	Devrinol	United Phosphorus
Trifluralin	Treflan	Dow
Oxyfluorfen	Goal	Dow
Bensulide	Prefar	Gowan
Sethoxydim	Poast	BASF, MicroFlow
Paraquat	Gramoxone Extra	Syngenta
Glyphosate	Roundup	Monsanto
Clomazone	Command	FMC, UAP

Table 2. Unregistered pesticides tested on cabbage in Minnesota and Wisconsin

Active Ingredient	Trade Name	Manufacturer
Insecticides		
Not yet available	F-0570; Active ½ of Mustang	FMC
Not yet available	F-1785; Selective aphicide	FMC

Table 3. Description of Pests and Pathogens of Cabbage

Insect Pest	Symptoms
Imported cabbageworm *(Pieris rapae)*	Chews irregular shaped holes in leaves; tend to feed on edge of leaves
Cabbage looper *(Trichoplusia ni)*	Chew large, ragged holes in leaves, moving towards center of plant
Diamondback moth *(Plutella xylostella)*	Smallest of 'big 3' lep pests, larvae; 5/16", initially leafminers, move onto leaves on which to feed causing 'windowpaning'
Flea beetle *(Phyllotreta spp.)*	Feeding causes small gouge-like holes resulting in shot-holed appearance
Cabbage maggot *(Delia radicum)*	Feed on root hairs causing plants to turn off-green color
Cabbage, Turnip and Green peach aphid *(Brevicoryne brassicae, Lipaphis erysimi, Myzus persicae)*	Feeding can result in yellow, curled and stunted leaves
Seedcorn maggot *(Hylemya platura)*	Feed below soil surface causing plants to become discolored
Thrips *(Thrips tabaci)*	Feeding causes white/brown patches to form on foliage
Fungi/Bacteria	**Symptoms**
Alternaria leaf spot *(Alternaria brassicae)*	Dark spot on seedling stem; damping off or stunting of seedling.
Black rot (*Xanthomonas campestris*)	A 'V' shaped area develops along the outer margin of the leaves, dark in color and then gray once the tissue dies.
Black leg (*Phoma lingam*)	Elongated, tan, sunken lesions develop along the stem just above the soil line; leaf spots later develop purple colored margins.
Clubroot (*Plasmodiophora brassicae*)	Abnormal enlargement of root tissue; leaves may also wilt and/or become yellow.
Downy mildew (*Peronospora parasitica*)	Yellow-brown spots appear on upper portion of leaves while white fluffy growth develop under leaves.
Wirestem (*Rhizoctonia solani*)	Plant tissue becomes water-soaked, collapses and dies; can also cause tough, woody stem to develop.
Yellows (*Fusarium oxysporum*)	Yellow discoloration of leaves.
White Mold (*Sclerotinia sclerotiorum*)	Infected tissues become water-soaked and collapse; covered with white fungal growth; black fungal sclerotia form on infected tissues
Damping off (*Pythium spp, Rhizoctonia solani*)	Decay of seed and death of seedlings.

Table 4. Efficacy Ratings of Pest Mgmt. Tools for Control of Weeds in Cabbage.

	Weeds of cabbage[1]															
Mgmt. tool	**BG**	**CG**	**FP**	**F**	**GG**	**YN**	**AM**	**G**	**JW**	**LQ**	**NS**	**PW**	**P**	**RW**	**SW**	**V**
Registered Herbicides																
Napropamide (Devrinol)	G[2]	G	G	G	G	NR	NR	P	NR	F	NR	G	G	NR	P	NR
Bensulide (Prefar)	G	G	G	G	G	NR	NR	NR	NR	F	NR	F	F	NR	NR	NR
Trifluralin (Treflan)	G	G	G	G	G	NR	F	NR	NR	G	P	G	G	P	P	P
Clomazone (Command)	G	G	G	G	G	NR	F	P	F	G	P	P	G	G	G	G
DCPA (Dacthal)	G	G	G	G	G	NR	NR	NR	P	G	NR	F	G	NR	NR	NR
Oxyfluorfen (Goal)	P	F	F	P	P	NR	F	G	F-G	G	G	G	G	G	G	F
Glyphosate (Roundup)	G	G	G	G	G	F	G	G	G	G	G	G	G	G	G	G
Paraquat (Gramoxone)	G	G	G	G	G	G	G	F-G	G	G	G	G	G	G	G	G

Sethoxydim (Poast)	G	F-G	G	G	G	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Metolachlor (Dual)	G	G	G	G	G	F-G	P	F	F	F	E	G	G	P	P	P
Clethodim (Select)	G	G	G	G	G	NR?	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Other Pest Mgmt. Aids																
Cultivation	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Rotation	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?

[1]Weed abbreviation key: BG=barnyard grass, CG=crabgrass, FP=fall panicum, F=foxtails, GG=goosegrass, YN=yellow nutsedge, AM=annual morning glory, G=galinsoga, JW=jimsonweed, LQ=lambsquarters, NS=nightshade, PW=pigweed, P=purslane, RW=ragweed, SW=smartweed, V=velvetleaf

[2]Efficacy ratings: E=excellent (90-100% control), G=good (80-90% control), F=fair (70-80% control), P=poor (<70% control), ?=no data but some potential efficacy, NA=not applicable and/or not used, NR=not registered for use.

Table 5. Efficacy Ratings of Pest Mgmt. Tools for Control of Insects in Cabbage.

	Insect Pests of Cabbage[1]						
Mgmt. Tool	**CL**	**ICW**	**DBM**	**CM**	**A**	**FB**	**T**
Organophosphate Insecticides							
Diazinon (Diazinon 50WP)	NR	F-G	NA	F	F	NR	NR
Chlorpyrifos (Lorsban 50W)	NR	F	P	G	?	G	NR
Dimethoate (Dimethoate 4E)	NR	NR	NR	NR	F	NR	P
Disulfoton (Di-Syston 8)	NR	NR	NR	NR	G	G	?
Naled (Dibrom 8)	P	P	P	NR	?	NR	NR
Oxydemeton methyl (Metasystox-R)	NR	NR	NR	NR	G	NR	?
Carbamate Insecticides							
Carbaryl (Sevin XLR Plus)	P	G	G	NR	NR	E	NR
Methomyl (Lannate LV)	F	F	F	NR	NR	NR	NR
Other Registered Insecticides							
Lambda cyhalothrin (Warrior)	G	E	E	NR	F	E	G
Bifenthrin (Capture 2EC)	E	E	E	NR	G	E	G
Permethrin (Pounce, Ambush, Waylay)	G	E	E	NR	?	E	NR
Cypermethrin (Ammo 2.5EC)	G	E	NR	NR	?	E	G
Esfenvalerate (Asana XL)	G	E	NR	NR	NR	G	NR
Spinosad (SpinTor 2SC)	E	E	E	NR	NR	NR	?
Emamectin benzoate (Proclaim)	G	G	E	NR	NR	NR	NR
Indoxocarb (Avaunt)	G	E	E	NR	NR	NR	NR

***Bacillus thuringiensis* (MVP, Javelin, Dipel DF)**	F-G	FG	G	NR	NR	NR	NR
Fenpropathrin (Danitol)	G-E	G	NR	NR	NR	NR	NR
Zeta cypermethrin (Fury, Mustang)	G	G-E	G	NR	G	E	G
Endosulfan (Thiodan 3EC)	P	G	P	NR	?	?	NR
Tebufenozide (Confirm)	G	G-E	P	NR	NR	NR	NR
Imidacloprid (Admire 2F, Provado 1.6F)	NR	NR	NR	NR	E	NR	NR
Soap (M-Pede)	NR	NR	NR	NR	P	NR	NR
Products Not Yet Registered							
F-0570 (Aphicide)	?	?	?	?	?	?	?
F-1785	NA	NA	NA	NA	?	NA	NA
Other	?	?	?	?	?	?	?
Other Management Aids							
Cultivation	?	?	?	?	?	?	?
Rotation	?	?	?	?	?	?	?
Other	?	?	?	?	?	?	?

[1]Insect abbreviation key: CL=cabbage looper, ICW=imported cabbageworm, DBM=diamondback moth, CM=cabbage maggot, A=aphids, FB=flea beetle, T=thrips

[2]Efficacy ratings: E=excellent (90-100% control), G=good (80-90% control), F=fair (70-80% control), P=poor (<70% control), ?=no data but some potential efficacy, NA=not applicable and/or not used, NR=not registered for use.

Table 6. Efficacy Ratings of Pest Mgmt. Tools for Control of Diseases in Cabbage.

	Diseases of Cabbage[1]						
Mgmt. Tool	**ALS**	**BR**	**BL**	**CR**	**DM**	**W**	**Y**
B2 Carcinogenic Fungicides Currently Labeled							
Chlorothalonil (Bravo)	G	NA	NA	NA	G	NA	NA
Maneb (Maneb, Manex)	G	NA	NA	NA	G	NA	NA
Other Registered Fungicides/Bactericides							
Copper (Kocide)	NA	P-F	NA	NA	NA	NA	NA
Pentacloronitrobenzene (Terraclor)	NA	NA	NA	F-G	NA	G	NA
Fosetyl-Aluminum (Aliette)	NA	NA	NA	NA	F	NA	NA
Captan (Captan)	NA	NA	NA	NA	NA	F	NA
Products Not Yet Registered							
Strobilurins	E	?	?	?	?	?	?
Other Management Aids							
Tillage	?	G	?	?	?	?	G
Cultivation	?	?	?	?	?	?	?
Rotation	E[3]	E[3]	E[3]	E[3]	E[3]	E[3]	E[3]

[1]Insect abbreviation key: ALS=alternaria leaf spot, BR=black rot, BL=black leg, CR=club root, DM=downy mildew, W=wirestem, Y=yellows

[2]Efficacy ratings: E=excellent (90-100% control), G=good (80-90% control), F=fair (70-80% control), P=poor (<70% control), ?=no data but some potential efficacy, NA=not applicable and/or not used, NR=not registered for use

[3]Rotation of crops is ineffective if less than 5-6 years

Table 7. Field Activity Timeline for Cabbage.

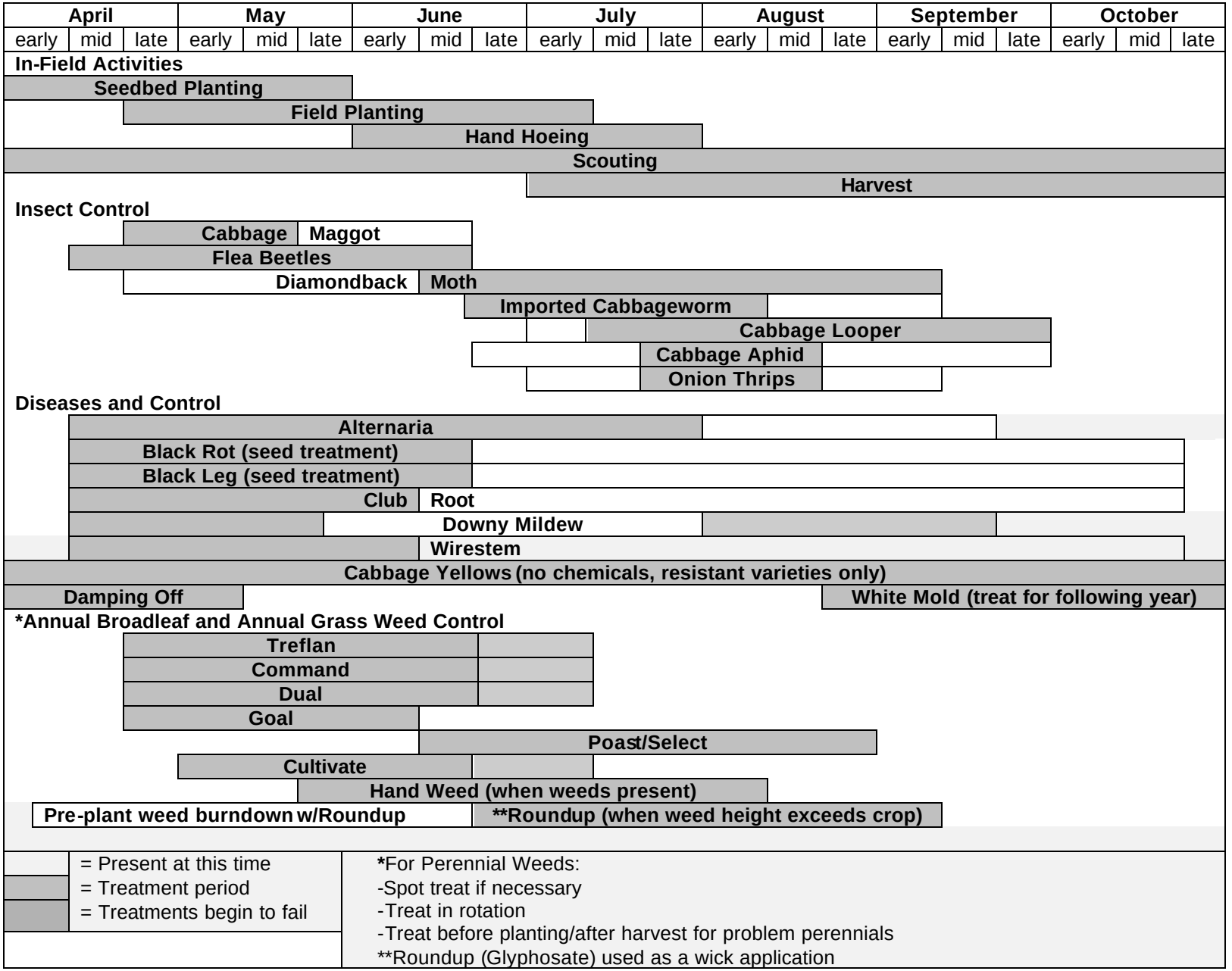

Table 8. Worker Exposure Times for Field Activities.

In-Field Activity	Per 10 acres				
	People	Hours/Person	Total hours	Actual Exposure hrs**	% of Total Acres
Planting (Transplanting)	10	12	120	120	50
Planting (Direct Seeded)	1	5	5	0.25	50
Irrigation	1-3	1	1-3	1-3	<10
Scouting*	1	1/week (8 wks)	8	8	100*
Hand hoeing	20	1	20	20	15
Cultivation	1	6	6	0	95
Harvest-Hand (Fresh)	20	7 hrs/day (3 days)	400	400	100
Harvest-Mechanical (Processed)	2	12	24	0	100
Chemical Application: Weeds	1	0.25 (1-2 apps.)	0.25-0.50	0.06-0.13	100
Chemical Application: Diseases	1	0.25 (1-2 apps.)	0.25-0.50	0.06-0.13	5-10
Chemical Application: Insects	1	0.25 (2-6 apps.)	0.5-1.50	0.06-0.13	100

*Actual “scouted” acreage is a representative fraction of total planted acreage.

**Due to use of enclosed cab tractor-rigs for planting/chemical application/mechanical harvest

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