Sweet Corn

Pest Management Strategic Plan

(North Central States)

(Posted Sept 2003)

Information on critical pest management practices
and priority issues developed at a workshop in Madison,
Wisconsin, on the 17th and 18th of December, 2002.
Also containing comments of a subsequent review.

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Strategic Plan Development: An Overview

The purpose of a Pest Management Strategic Plan is to provide a document that communicates the role of pesticides and pest management strategies used to control crop pests from an industry perspective, with cooperation and verification from sweet corn pest management specialists at Land Grant institutions. While this information is primarily used by the Environmental Protection Agency (EPA), it also provides to the USDA, Land Grant Universities, and pest management stakeholders a prioritized "to do" list of research, education, and regulatory issues. Strategic Plans may also be helpful to the sweet corn industry as a means of evaluating progress on those issues.

This document has been prepared to convey to the reader the pest management challenges confronting Midwestern sweet corn producers. Though it is not all-inclusive, it is meant to be generally representative of sweet corn pest management in the North Central Region.

This initial version of the Pest Management Strategic Plan is based on information assimilated from previously completed sweet corn profiles. The document was further developed from input gathered from producers, consultants, and other technical experts attending a workshop in Madison, Wisconsin on the 17th and 18th of December, 2002. In addition to providing input on pests and pest control methodologies, attendees identified research, education and regulatory issues that impact producer profitability and environmental quality. The final task of the attendees was to prioritize the issues that they thought were the most critical to sweet corn pest management.

Data completeness and accuracy:

The intent of this report is to provide the EPA with the pest management perspectives of sweet corn producers, consultants, and other pest management specialists. As such, it primarily reflects the comments and inputs of those parties who attended the workshops. As with any group of individuals, the scope of knowledge as well as opinions of participants vary greatly, and in its current form this document captures that scope and diversity.

Another factor which affected the completeness of information was the method used to collect information during the meetings. Time constraints typically dictated that only those pests which are consistently a problem be addressed during the meeting. Although the document was widely circulated for review to correct the lack of attention given to less common pests, there yet remains some uneven completeness of data. The editors and reviewers have taken significant measures to excise faulty or misleading information, but it has not been our intent to remove or alter information which was provided at the workshops that does not harmonize with "conventional wisdom". This Strategic Plan should be viewed as a work in progress; future versions will undoubtably result in an improved product.

Executive summary:

The twelve states of the North Central Region produce about one half of the processed sweet corn in the United States. Most of this production resides within an area from western Indiana through northern Illinois, and southern Wisconsin and Minnesota. Fresh market sweet corn is also grown throughout the Midwestern region for sale at retail grocery stores and roadside stands. The total value of sweet corn grown within the United States exceeds $800 million. Sweet corn is an important table vegetable with Americans eating about 30 pounds of corn per person per year (canned, fresh and frozen).

The profit margins for most sweet corn tends to remain quite low, being typically tied to grain corn prices. With marginal returns, producers are looking for opportunities to reduce the costs and risks and maintain their economic viability. This Pest Management Strategic Plan offers a glimpse into the opportunities and challenges producers face in trying to maintain a profitable and secure industry.

The original draft of this Pest Management Strategic Plan was developed from input provided by land grant pest specialists. The draft was then presented to sweet corn producers and industry representatives at a workshop held in Madison, Wisconsin on the 17th and 18th of December, 2002. Within the context of this workshop participants discussed their greatest pest management challenges and outlined their priorities for research, education, and regulatory action.

The highest priority among producers was the need to insure that adequate pesticides would be available for pest control in sweet corn in the coming years. This could be done through three different mechanisms. First, maintain the registrations of a number of existing pesticides. Some compounds, such as atrazine and the pyrethroids, continue to be essential prophylactic and curative treatments for which no suitable alternative has yet been found. Producers felt it was of utmost importance to communicate to regulatory agencies their considerable stewardship efforts with these compounds in the hope that they will continue to remain available to growers.

Second, growers would like to see cooperative efforts that lead to expanding the label of some pesticides currently labeled for field corn to include sweet corn. Although in some cases some additional research may need to be conducted to determine if residues may be a problem, in many cases it would not be a complex procedure to expand these labels.

Finally, growers would like to see manufacturers encouraged to seek out new synthetic or plant incorporated pesticides. Growers perceive that the Roundup Ready and Bt technologies have been a disincentive to new product development and are concerned about having sufficient mechanisms to control pests in the future.

Though a number of other issues surfaced during the discussions, perhaps the common recurring theme of the workshop could be expressed as a concern about resistance development in all pests. Growers expressed the need to have more information regarding managing pests to forestall resistance and methods which could be useful in predicting its development.

A number of pests were identified as being of particular concern. These included common smut, rusts, corn earworm, Stewart's wilt, and corn rootworm. The general agreement of the participants was that more information on these pests, such as life cycle and impact on the crop, would be useful to growers. Refer to the table of issues and priorities that follows for the specific text of these priorities.

Research, Education, and Regulatory Priorities for Sweet Corn.

Research	Regulatory	Education
The widespread adoption of Roundup Ready and Bt hybrids has become a disincentive for the development of new products. The sweet corn industry needs new pesticide products, especially herbicides, to combat newly invasive weeds, and weeds which are becoming resistant to current herbicides. Research needs to continue into new synthetic compounds so that pests can be controlled as necessary.	A number of pesticides are labeled for field corn that may have acceptable uses for sweet corn. The possibility of expanding the label to include sweet corn should be investigated for the following products; Callisto, Camix, Lumax, Option, Liberty, Poast, acetachlor. Regulatory agencies, the sweet corn industry, land grant partners, and manufacturers should seek to support these labels.	GMO enhanced crops provide growers and consumers with a number of benefits. The reluctance of consumers to accept GMO sweet corn is a barrier to their adoption. Consumers need to be educated on the advantages of GMO crops. These advantages might include for example; more biodiversity, less pesticide use, and human and environmental safety.
Common smut is one of the more devastating sweet corn diseases. Research is needed to screen hybrids for reaction to common smut, and investigate mechanisms of resistance. Hopefully this will lead to the development of hybrids with greater resistance to this disease.	For some sweet corn insects, control is achieved almost exclusively through the use of pyrethroid insecticides. Corn earworm, European corn borer, and the fall armyworm would become serious problems if these insecticides were lost. There is a critical need to maintain registration of these insecticides.	Corn earworm is one of the most serious insect pests of sweet corn and requires regular insecticide sprays when populations are high. Growers, especially fresh market sweet corn growers, need to be educated regarding corn earworm monitoring procedures so that pesticide applications can be reduced. The trapping networks and information delivery mechanisms regarding this insect should be better coordinated.
Leaf rust; timing of initial applications of strobilurins needs to be examined. Because these compounds are more efficacious than other fungicides, they may be applied later in the disease cycle, thus allowing for a better assessment of whether chemical control is actually needed. Strobilurin-resistant fungi are likely to occur- so resistance management strategies should be developed. Hybrid screening and resistance breeding need to be continued.	Registrants and regulatory agencies should update rotational restrictions regarding atrazine use on sweet corn. The current label is based on older, higher use rates, usage patterns. Sweet corn growers, who often grow other vegetable crops in their rotations, are now unnecessarily restricted on rotations.	Sweet corn diseases can seriously reduce crop yield and quality. Since the number of fungicide products is limited to a couple of modes of action, it is imperative that disease resistance management schemes be implemented now to retain the usefulness of these products. Growers need more information on how to implement pesticide resistance management for sweet corn diseases.

Additional Research Priorities

Corn rootworm is a recurring and important pest on sweet corn. Producers need more complete corn rootworm larvae insecticide efficacy trails on sweet corn to guide their insecticide application decisions.

Producers need a corn rootworm beetle model for overwintering and for summer survivorship (forecast similar to flea beetle model). Producers also need a better understanding of the extended diapause (Eastern part of region) variant of Western corn rootworm.

Stewart's wilt/flea beetle; Producers need to have better information from which to predict size of flea beetle populations. This could be useful in determining when to apply seed treatment insecticides or to avoid the use of moderately susceptible or susceptible hybrids. It would be helpful to have an overwintering model for flea beetles.

Research should investigate the development of systemic plant resistance or tolerance to insects and herbicides in a non-GMO way (such as was used to develop Clearfield or Poast tolerant sweet corn).

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General Production Information

Background:

Over 700,000 acres of sweet corn (*Zea mays*) are grown in the United States each year. This acreage consists of sweet corn for both fresh market (242,000 acres) and processing (467,000 acres). The twelve North Central Region states are responsible for approximately 50% of the nation's processed sweet corn. Within this region the majority of the commercial production of processed sweet corn is located near the processing plants which dot the region from southern Minnesota and Wisconsin to northern Illinois and Ohio. While some of the fresh market acreage is grown under contract, a considerable amount is produced for roadside stands and local farmers' markets. The fresh market production for the region is distributed throughout the North Central Region with higher production occurring near large cities.[1]

Markets:

Sweet corn consumption has increased considerably over the past 30 years. In 1970, each American consumed approximately 5.8 pounds of corn/year while this amount has increased to aboaut 30 pounds/year today. There is a large international market as well, as indicated by sweet corn imports and exports. The total export value of canned sweet corn in 2001 was $220 million. Canned and frozen imported sweet corn, primarily from Canada, totaled $16 million in 1999.[1]

Table 1. Area, production, and value per hundredweight and per ton, by State, 2001

Processed sweet corn	2001 Acres	2001 Tons	2001 Dollars per ton
IL	**17,500**	**116,610**	**126.00**
MN	**130,200**	**794,720**	**68.80**
WI	**98,800**	**657,640**	**65.80**
US	446,450	3,142,840	72.90
Fresh market	2001 Acres*	2001('000) boxes**	2001 price per box
IL	**5,700**	**1,300**	**11.18**
IN	**6,000**	**1,088**	**9.63**
MI	**10,300**	**1,437**	**10.75**
OH	**15,400**	**3,044**	**7.91**
WI	**7,300**	**1,363**	**8.17**
US	255,900	64,328	8.43

* An inability to track the numerous growers who produce sweet corn for roadside markets and local outlets may result in some underestimation of total production of fresh market. A box is considered to be 50 ears and requiring about 43 pounds of bulk mechanically harvested corn.

** Estimated. The above tables available from USDA-NASS Agricultural Statistics 2002 with conversion of hundred-weight figures to the market convention of boxes harvested. Box prices may appear high but are influenced by roadside market prices.

http://jan.mannlib.cornell.edu/reports/nassr/fruit/pvg-bban/vgan0102.txt

Cultural Practices

Planting, tillage, and fertilization:

Sweet corn is similar to field corn and thrives under similar conditions. The deep fertile soils, moderate rainfall and temperate weather of the Midwest are ideal for high yields and quality. Relative to field corn, sweet corn is a high value crop and as much as 20 percent of all sweet corn may be irrigated. Fields are generally fertilized at levels below that of field corn and may be side-dressed with an application of nitrogen later in the season. Fields are generally tilled to reduce weed competition.

Sweet corn must be harvested within a very short time of optimal maturity so planting dates are staggered over a period of weeks to permit a longer harvest period. Another tactic used by producers to lengthen the harvest period is to plant hybrids with different maturity dates. The typical early planting date for sweet corn is one to two weeks before the frost free date in the region but may be somewhat later for the Sh_2 genotypes. The planting period may extend into the first week of July. Harvest timing for the processor will be scheduled to maximize plant utilization. For the fresh harvest timing is scheduled to coincide with desirable market windows. Harvest timing will depend on genotype, however. The Sh_2 types dominate the fresh market trade and are now being used more extensively by processors. Early planting tends to be less critical for processors, as there is no market advantage for early processed corn, but it does help distribute loads at processing plants. For fresh market producers the last planting can extend to the first week in July. Producers who grow sweet corn on contract are always assigned planting dates by the processor for the corn hybrids they grow.

Average field size for sweet corn produced under contract is 40-80 acres. The range of acreage contracted per grower is 80-240 acres. Most fresh market sweet corn fields range in size from 1- 40 acres with a few exceeding 100 acres.

General pest control comments:

Most herbicides are applied at pre-emergence because sweet corn is not very competitive with weeds and there are few post-emergence weed control options. Nicosulfuron, atrazine, bentazon, and carfentrazone may be used for postemergence control of wild proso millet and other weeds. Nicosulfuron is restricted to a few tolerant lines and is used for processing sweet corn only. Insect and disease control are very important for sweet corn produced for the fresh market. Consumer expectations for blemish free produce results in regular insecticide and fungicide use. An analysis of NASS survey data for the U.S. indicates that fungicide and insecticide use on fresh market sweet corn was higher than for processed corn (i.e. over 4 pounds a.i. per acre vs. 0.15 - 0.66 pounds a.i. per acre)[3]. However, this difference may result from the greater portion of the fresh market sweet corn being produced in the southern U.S., an area where pest pressure is considerably greater than in the upper Midwest.

The amount and frequency of pesticide use is determined by which pests are present and by prevailing weather conditions. Survey statistics indicate that insecticide and fungicide use can vary by a factor of two from year to year. Sweet corn producers are sensitive to the issue of pesticide reduction, and use non-pesticide methods of control whenever it is perceived that they are economically viable. Crop scouting is practiced on the majority of acres (~85%). Processing plant personnel and field reps will scout close to 100 percent of acreage under their contracts. Crop consultants and the growers play a major role in scouting fresh market sweet corn. Processors rely on pheromone traps for detection of corn ear worm in over 70% of contract fields. Blacklight traps are also used for monitoring European corn borers. Field sanitation and water management are other options utilized but with less frequency.[3] Adjusting planting dates is used by sweet corn producers to stagger harvest for processing plants and for continuity of fresh market sales.

GMO comments:

GMO sweet corn has met great resistance world-wide. The perception that many consumers have is that GMO's are harmful and hence, sweet corn hybrids with GMO traits have not yet been accepted by consumers. If consumers were to accept GMO sweet corn, the Bt type hybrids could reduce or eliminate spraying pesticides for control of corn borers and possibly corn earworms and fall armyworms. It is also possible that Roundup Ready or Liberty Link sweet corn could reduce the risks of crop losses many growers now face should atrazine be cancelled. Education is needed to demonstrate that GMO plants and seeds can be safe to humans and the environment. It is also important to communicate that GMO plants may increase biodiversity while reducing unwanted chemicals in our water, soil, air, and food.

Synthetic chemical free production:

The production area of certified organic sweet corn is a small fraction (<5%) of that which is conventionally produced. Nearly 95% of the organically grown sweet corn is scouted for pests and nearly all that is done by the grower. The use of beneficial organisms (46%), habitat provision (67%), resistant hybrids (80%), and water management (33%) and adjusting the planting date (56%) were quoted on surveys as practices regularly implemented by organic growers. [3]

Harvest practices and yields:

The average harvest date for sweet corn is 70-85 days after planting. When corn is planted very early in the season it is not uncommon for 80 day corn to require 100 or more days to actually mature. Some fresh market producers employ manual labor for hand picking ears from the plant while larger commercial producers often use mechanical equipment. Due to the influence from chain store buyers and the cost of harvesting equipment, the trend in recent years has been back to hand harvesting. This trend may continue as long as labor is available. Sweet corn yields range from 4 to 9 tons/acre. Small plots harvested by hand may typically yield 12 to 20,000 ears per acre.

Because sweet corn will rapidly lose freshness and begin to degrade after harvest, refrigeration or icing fresh market sweet corn during transport can be employed. Lowering the temperature helps to retain the high sugar content within the kernels before reaching market. Overly mature crops may be harvested as cattle fodder or used for corn silage.

Pest Resistance Issues

Herbicides: Weed resistance to herbicides is now recognized as a major threat to sweet corn production. Pre-emergence applications of atrazine followed by postemergence applications of atrazine were relatively common and led to resistance. Weed species resistant to the triazine herbicides now include common lambsquarters, giant foxtail, kochia, smooth and redroot pigweed, and velvetleaf.

Insecticides: Insect resistance development is of concern in both fresh market and processed sweet corn. Fields often receive multiple insecticide treatments as a means of reducing the insect contamination of fresh or processed corn that is deemed unsatisfactory by consumers. European corn borer, *Ostrinia nubilalis* Hübner, and corn earworms *Helicoverpa zea* Boddie, are the pests which are of principal concern in the North Central Region. Late-planted sweet corn is more susceptible than early-planted fields and typically requires more insecticide treatments. The European corn borer and the corn earworm have other hosts including field corn, and as a result have little potential to develop resistance from current sweet corn treatments.

Fungicides: Although resistant hybrids tend to be the most common control mechanism, resistance to fungicides is of greatest concern in fresh market fields which may receive repeated fungicide treatments. A new race of common rust has recently appeared that is virulent to Rp1D hybrids. Host resistance to common rust in sweet corn was based entirely on Rp1D until 2001.

Worker Exposure Issues

Applicators/loaders: Approximately 90% of all herbicides applied to sweet corn grown under contract are applied with equipment utilizing air filtration systems. It is estimated that an applicator operating a ground rig will take approximately 1 minute for each acre/pesticide application. This includes mixing, loading, and application, but not transit time to get to and from the fields. Each acre of contract sweet corn receives approximately two herbicide applications per season, one pre- and one post-emergence. Only 1 to 3 percent of contract sweet corn fields are treated with a soil applied insecticide at planting. Later in the season, however, nearly all fields grown for contract receive 2 to 5 post-plant insecticide treatments for European corn borers and corn earworms (average of 3). More than 90% of the foliar applied insecticides are aerially applied. Insecticides used on small plots produced for roadside stands and farmer's markets are applied with a host of less sophisticated equipment. It is unknown whether locally-grown, small sweet corn acreage not produced under contract has less frequent insecticide applications than acreage grown for contract.

Planting takes approximately one day for each 100 acres of corn grown. During planting, growers handle bags of seed that have a fungicide seed treatment, refilling planting boxes an average of five times with approximately 10 minutes per refill. Leather gloves worn during refill operations are typically the only safety equipment used.

Other workers exposed to pesticides include the applicator, handlers/loaders, planter operators, chemical delivery people, and the laundry service workers who wash such clothes. Contact with pesticides may occur as a result of equipment maintenance and calibration, normal pesticide application, equipment clean-up, or spills. For estimations of worker exposure for processed and fresh market sweet corn see Appendices F and G.

Crop scouts: Some crop scouting takes place during the six week period immediately after planting. During this period physical contact between the crop scout and pesticide residues on the soil or emerging crop is minimal. After this initial period some insect and disease scouting in standing corn is necessary. Although many field scouts wear vinyl rain suits while in the fields due to the heavy dew that can occur, it is possible that bare arms and skin may be exposed to latent pesticide residue. Furthermore, to determine actual levels of pest infestation some handling of plant material may be required by the scout in the field. Good communication between field scouts and the grower minimizes exposure to residues. For estimations of time in field and exposure see Appendices F and G.

Field workers: The availability of effective herbicides has reduced the need for hand hoeing or roguing in fields. More hand hoeing takes place on very small production plots grown for roadside markets. As a practical matter commercial sweet corn is rarely hoed, and then usually for the purpose of thinning a stand due to an errant planter unit or other miscue.

Harvesters: For fields harvested by machines the operator has little or no contact with the plant or the ears. Small plot acreage harvested by hand necessitates contact with plant leaves which may have latent residues of post-emergence applied insecticides or fungicides. Roadside growers may pick the ears and toss them onto a wagon or into a tote sack. Fresh market grower shippers will, if they pick by hand, most often also pack the corn in the field using a harvest aid or “mule train”. This operation may involve the grower, his family, and/or other laborers. For sweet corn harvested by hand, gloves made of cloth or light leather are generally used. See Appendices F and G for estimated exposure of harvesters.

General Pesticide Application Information

Herbicides: It is estimated that less than 10% of all herbicides are applied to sweet corn in the granular formulation. Ninety-nine percent of all herbicides are applied by ground application equipment. New, water-dispersable herbicides available as a dry formulation have reduced dust inhalation risk. Dry formulation packaging has also reduced container disposal issues. Exposure by farmers or custom applicators during mixing and loading has not been well researched to date, but we can speculate that the increased usage of dry-formulated pesticides has great potential for reducing handler exposure.

Insecticides: Soil insecticides are applied by the grower during planting while foliar applied insecticides are applied once the crop has emerged from the soil. Small acreage growers who apply insecticides may be at higher risk of exposure than large acreage growers who contract with aerial applicators. Nearly 90% of all foliar insecticides are applied by aerial application to large production fields and result in little or no exposure to the applicator. Smaller fields would typically use ground application equipment and may result in a higher incidence of exposure. Insecticide handling time is approximately 10 minutes for every 100 acres of sweet corn for aerial application.

Fungicides: Foliar fungicides on sweet corn has been estimated at 10 to 50 percent of the acreage annually.

Post harvest handling: Post harvest exposure to latent pesticide residues may be an issue for fresh market sweet corn. In fresh market production, corn is graded, sorted, and then packed by hand prior to cooling. Processed corn is inspected by hand, after it has been husked, while it passes on a conveyor belt. The degree to which handlers, sorters, and graders use protective equipment is unknown.

Environmental Exposure Issues

General: Approximately 10-20% of sweet corn is produced on irrigated land. Although no figures are available, much of the irrigated land in the Midwest is on sandy soils with shallow groundwater. Therefore, where sweet corn is produced on irrigated land there is an increased risk of groundwater contamination by pesticides. Although many small acreage producers are close to large cities, the fields of most contract growers will be several miles from large metropolitan centers.

Herbicides: Cyanazine, which has been associated with ground and surface water contamination, has been removed from the market and will no longer be available for sweet corn producers. Atrazine, another herbicide that has been found in ground and surface water, is widely used by most sweet corn

producers, but is not available in some regions (Parts of Wisconsin) due to local restrictions. The acetamide group of herbicides (alachlor, metolachlor, dimethenamid) are used on up to 90% of the sweet corn in the region for preemergence grass control. They are known to contaminate water resources and can be a problem in areas with very shallow groundwater or high levels of soil erosion. Post emergence herbicide use on sweet corn poses less environmental risk than soil applied products.
Insecticides: With the low use (2-3%) of soil insecticides there is little risk to avian or aquatic life. The widespread use of the pyrethroid class of insecticides may reduce populations of beneficial insects in localized areas.

Product Registration Issues

Herbicides: Herbicide registration losses (with the exception of cyanazine) have been few over the last several years. However, restrictions have been placed on many herbicides in an effort to reduce contamination of surface and groundwaters. Atrazine, alachlor, and paraquat are all restricted-use pesticides. They may be purchased and applied only by, or under the direction of, certified or licensed applicators. Groundwater advisories have been added to many labels to prevent mixing, loading, and application in areas of high risk for runoff or leaching. Many additional restrictions have been placed on atrazine to limit its application and reduce contamination of surface and ground water. Additional restrictions likely will be imposed on individual products to limit drift, wildlife exposure, and residues in foods, in addition to groundwater contamination. In southern Wisconsin the loss of atrazine and cyanazine has resulted in a shift to less effective, and more expensive weed control options.
Section 18s were issued for glufosinate in 1999, carfentrazone in 2000, and mesotrione in 2002; in Wisconsin for use in the atrazine prohibited areas. Products such as metolachlor, alachlor, and atrazine are also under scrutiny in Minnesota due to ground and surface water issues in areas where sweet corn is grown for processing.
Insecticides: Gaucho seed treatment for control of corn flea beetle and Stewart's wilt is now registered. Cancellation is not imminent for other insecticides as of publication date. Cruiser is to be given a label in 2003.
Fungicides: A section 18 was granted for Imazilil for control of seed and soil-borne fusarium sp. and penicillium sp. during 1999 and 2000. Imidacloprid has also received a section 18 in Idaho and Minnesota for seed to be planted in the Midwest and a few Eastern and NE states.

Critical Alternative Issues:

Specific pesticides or pesticide groups are herein given ratings according to their level of significance to the commodity. Although non-chemical or organic methods of pest management are employed for many production systems, our intent is to focus on commercial agriculture, which generally involves conventional pesticides. There are three rating levels: Level A: product critical, no acceptable alternatives, loss of product would cause regular and drastic changes in production, safety, or commodity price. Level B: product essential, alternatives limited in application, loss of product would cause significant changes in production, safety or commodity price. Level C: product fundamental, alternatives exist, loss of product would cause few changes in production, safety, or commodity price.
Critical Herbicides: (Atrazine, level A,.) The most critical pesticide issue for sweet corn production is the possible loss of atrazine. Currently there are no acceptable alternatives for broadleaf weed control for this herbicide. Although nicosulfuron, (Accent) is registered for use on some select processed sweet corn hybrids, it cannot be used on fresh market corn and it controls very few broadleaf weeds. The use of 2,4-D as a substitute for atrazine is greatly limited due to its propensity for crop injury. Bentazon and carfentrazone control a few broadleaf weed species, but they lack the broad spectrum that is required. Bentazon could be considered Level B herbicide because it has a critical role in use with atrazine in allowing lower use rates and expanding the atrazine spectrum of control at those lower rates. Atrazine is very commonly used on sweet corn and its loss would result in significant changes in production, most notably a reduction in sweet corn acreage planted and a reduction in per acre yields, and hence a significant increase in cost of the sweet corn produced. The loss of atrazine would also require more

in-field hoeing of weeds, exposing field workers to more insecticides.

The loss of the acetamides as a group could also be considered level A significance. Used primarily for grass control, there are no alternatives that provide equivalent efficacy. Butylate and EPTC as alternatives may provide some control but at the risk of increased crop injury. Neither of these products have formulations that are generally available, however. Pendimethalin generally provides less efficacy than the acetamides but its use significantly increases the risk of injury. The loss of the acetamides would necessitate additional cultivations and would result in yield reductions of up to 30 percent in some years.

(All other individual herbicides, level C)

Critical Insecticides: (Pyrethroids as a group, level A) In an effort to reduce OP and carbamate residues on sweet corn, pyrethroids are now the product of choice for foliar-applied control of corn borer and corn earworm. If pyrethroids were no longer available sweet corn quality would decline significantly and prices would go up drastically. In addition, the amount of insecticide active ingredient would go up drastically. Gaucho seed treatment to control corn flea beetle and Stewart's wilt is critical in some areas (level A). (All other individual insecticides, level C)

Critical Fungicides: (Fludioxonil, "Maxim", or Mefenoxam, "Apron", level B, loss of both classed as Level A.) Both of these products are widely used as seed treatments for sweet corn. Unlike field corn, sweet corn is particularly vulnerable during germination. Super sweet hybrids have exceptionally low vigor during emergence. The protection afforded by these products can be critical in cool wet soils where Pythium and Fusarium species are prevalent. These products are also necessary for control of seed-borne and soil-borne Penicillium species.

Captan can be classified as an alternative to fludioxonil and mefenoxam but is less efficacious. ("Quadris", azoxystrobin, Level B) Although foliar treatment for rust has been minimal (on processed sweet corn) over the last decade, a virulent race has recently developed which affects Rp1D hybrids and may require more foliar fungicide over the next few years. Plant breeders will need from 3 to 6 years to breed greater resistance into current hybrids. Quadris is expected to provide the systemic protection necessary to protect the crop in the interim and use may approach 35 to 40 percent of the entire sweet corn crop. It is easy to imagine some years where the rust could devastate the crop without Quadris; suggesting a possible Level A ranking. For fresh market sweet corn zinc ion manebs are also considered important, especially for resistance management. (All other fungicides, level C)

Pipeline products

Herbicides: Although glufosinate resistant hybrids have been developed, consumers have not shown a willingness to accept transgenic traits in table food and widespread adoption remains in doubt. Glufosinate resistant hybrids have had some limited acceptance in fresh market sweet corn.

- Mesotrione - very promising new product in trials, safe on corn, and broad spectrum broadleaf weed control, would like to see registration soon!
- Clopyralid - relatively safe, but narrow spectrum, will have a good fit in some places.
- Carfentrazone - just registered, but narrow spectrum so must be mixed with atrazine to be useful, and can cause significant injury with certain weather conditions.
- Dicamba + diflufenzypyr - causes some crop injury, anticipating registration soon
- Halosulfuron - recently labeled, crop injury a concern, needs atrazine for control of many weeds

Insecticides: Bt sweet corn hybrids have been developed but have not yet been accepted by consumers. There is a need to find non-OP, non-pyrethroid insecticides, in the event that the EPA places restrictions on them. Work is being done on products such as SpinTor, Proclaim, and Avaunt, but they are either not registered for sweet corn(Proclaim), or too expensive compared to the pyrethroids.

Gaucho seed treatment for corn flea beetle and Stewart's wilt disease control needs to be fully registered (currently under section 18 registration). Cruiser (thiamethoxam) and clothianidin also are in development for seed application control of flea beetles and Stewart’s wilt.

Fungicides: Work with strobilurins from industry needs to be done, several potentially effective new products have been developed (BASF-500, Stratego, Tilt+, and trifloxystrobin). A non-strobilurin fungicide that is more efficacious than Tilt is needed for resistance management.

Co-occurrence of Pesticides

Herbicides: Atrazine will be used primarily with a grass control herbicide such as metolachlor, alachlor, or dimethenamid. These latter products are seldom used in combination with other acetamides and are not often used sequentially on the same field. (< 5% of crop) Atrazine is often used with bentazon for broadleaf control and is an ingredient in the package mix Laddok.

Insecticides: The majority of insecticide applications are foliar-applied pyrethroid treatments. Very seldom is more than one product applied during a single treatment. However, it is common, especially for larger growers, that more than one pyrethroid be applied in sequential applications. (> 90% of crop) Growers with smaller acreage may purchase a single product for repeated use.

Fungicides: The application of more than one foliar fungicide during a season, either in a combination or sequential application, is very rare. (< 1% of crop) The use of a combination of products to expand the efficacy of seed treatments is common. (>50% of seed treated)

Weeds

Weeds are present in every field every year. The severity of the weed population is determined by local management practices such as the previous crop, fall and spring tillage, crop rotation, and herbicide use. The prevalence of specific weeds throughout the region is dependent upon soil type, rainfall and moisture, temperatures, and day-length for the region. Although losses from weeds in field corn average from 3 to 7 percent annually, losses attributed to weeds in sweet corn total losses can be 15 percent or more.

Sweet corn yield losses due to weeds are predominantly caused by competition for soil moisture. In years when rainfall is limited, not only does the presence of weeds reduce the amount of moisture available for the crop, but a lack of rainfall early in the season also reduces the effectiveness of herbicides, resulting in an abundance of weeds. Stunting crop growth at any time during the season results in an overall reduction in each plant's potential to produce and fill a large ear, while moisture stress on the crop during the early ear formation can reduce the number of kernels which develop. Although less common, weeds also reduce photosynthesis by shading the corn plant. Because corn grows quickly and an upright growth habit, in order for significant shading to occur weeds must grow faster than the corn or must start growing before the corn emerges. Typically, dense populations of weeds are necessary for shading to have much effect on the overall yield of the crop. The reduction in yield from shading occurs as a result of the formation of smaller ears of corn on each plant.

In addition to the yield and quality factors mentioned above, weeds also provide a habitat for insects, and when found in sufficiently dense populations, can change the microclimate in the field to favor plant diseases. Some weeds may also be a problem at harvest as they clog machinery or reduce its efficiency in separating the ears from the plant.

As many as 30 different plant species are commonly found as weeds in agronomic crops in the North Central Region. Although it is beyond the scope of this publication to detail how each herbicide interacts with each weed, in addition to identifying plants as either grasses or broadleaves, there are some plant groupings that are useful to understanding the general tendency of groups of plants to tolerate or be susceptible to herbicides. These include plant life cycle, seed size and germination characteristics, and a tendency to develop resistance to herbicides.

Most common weeds can be divided into three categories: grasses, broadleaves, and sedges. Plants of a particular category may have a tolerance to herbicides through shared attributes such as physical characteristics, cell structure, or biochemical processes, which may prevent a herbicide from entering the plant, inhibit its movement within the plant, or deactivate the herbicide before it can attack plant processes. For example, the growing point of grasses is below the soil surface during early growth and is protected from the non-translocated post-emergence herbicides that are effective on emerged broadleaf weeds. Other shared physical characteristics, such as a protective leaf sheath which encloses newly emerging grass seedlings, or the ability of a broadleaf plant to generate new shoots from leaf axils, may also lend tolerance or susceptibility to herbicides. While there are many common characteristics that are shared by each category, there are also individual plant characteristics that separate individual species and result in differential susceptibility among plants within the category. The key to weed control is to select herbicides which have characteristics that fit the general category of weeds, but note specific weeds in the field that might respond differently from others to the candidate herbicides.

Plant life cycle also plays a part in weed tolerance to herbicides. Perennial weeds, such as Canada thistle, common milkweed, and bindweed, have deep and extensive root systems that allow them to regenerate new emerging shoots after existing ones have been killed. Most perennials, unlike annuals, require herbicides which are translocated to the roots for effective control. The root systems are so extensive that only multiple treatments over several seasons are sufficient to kill plants. Perennial plants also tend to invest more reproductive energy in their root systems than in seed production. As a result, few plants arise from seed and those which do are seldom a significant concern. The most effective herbicides for perennial weeds are those which translocate within the plant and will be foliar applied at a time when the plant is translocating photosynthates from the leaves to the roots. Although contact (non-translocated) and soil-applied herbicides may have some deleterious effect on the growth of perennial weeds they seldom provide effective long term control.

Weed seed size and germination characteristics also dictate which herbicides may be effective. Plants arising from larger seed, such as from cocklebur, jimsonweed, and velvetleaf, tend to germinate at soil depths and at times during the season (April, May or early June), where moisture is plentiful. Many of these weeds are difficult to control with pre-emergence herbicides only and may require post-emergence herbicides for adequate control.

On the other hand, small seed, such as from most grasses, pigweeds, and lambsquarters, tends to germinate at times throughout the season when light rains have moistened the soil surface or where crop residue keeps the surface moist (no-till). Of those weeds which do germinate late in the season, some are shade tolerant and grow well under the crop canopy to become significant problems (black nightshade, prickly sida), while others wither and die or never grow beyond a few inches in height. Weeds that tend to be problems late in the season must be controlled by herbicides which are persistent in the soil or controlled by late-season "rescue" post-emergence applications.

Finally, one other plant characteristic must be considered before a herbicide is selected; the presence of, or tendency to develop, herbicide resistance. There are 20 common weed species in the Midwest that now have resistance to herbicides. Though a particular species may not be resistant to herbicides some have a predisposition to develop resistance due to a genetic or physical characteristics. Some of these characteristics include cross-pollination, prolific seed production, and a genetic capacity to adapt. Plants which exhibit more than one of these characteristics are the most commonly found resistant plants (kochia, waterhemp, pigweeds). In nearly every field in the Midwest herbicide resistance is now of concern. Herbicide selection must focus on rotating herbicides or combining herbicides with different modes of action. http://www.weedscience.org/in.asp

Information on the level of control of weeds for listed herbicides is not given in this section but is presented in an aggregate table at the end of this document.

1. Annual Grasses

Biology and Life Cycle:

- Grass weeds germinate at soil depths from 1/8th of an inch to 2 or 3 inches. Seed size and dormancy are the controlling factors for when and where these seeds emerge. Large seeded weeds have greater seed food reserves and can emerge from greater soil depths where moisture is less variable than near the soil surface.
- Weeds germinate at various times throughout the season depending on environmental cues such as moisture availability and soil temperature.

- Weeds produce prolific numbers of seeds which may lie dormant for very brief (2 weeks) or long (10-20 years) periods before germination.
- Weed seeds are distributed by wind, water, birds, and mechanical harvesting equipment.

Pest Distribution and Importance:

- Annual grasses infest approximately 98% of all sweet corn acres. Many of these are controlled with preemergence herbicide applications and tillage.
- While usually not as competitive as broadleaf weed species, annual grasses can reduce crop yields when significant populations are present. This is particularly true in dry years, where competition for moisture early in the season can be critical for sweet corn development.

1a. Foxtails (*Setaria* spp.)

There are three important foxtail species: giant foxtail (*Setaria faberi),* yellow foxtail *(Setaria glauca)*, and green foxtail (*Setaria viridis).* At least one of these species can be found in nearly any sweet corn field in the North Central Region. While low populations cause little crop competition, because of seed production an unchecked population can quickly become a severe problem. A primary control method for foxtail spp. is the application of preemergence grass herbicides. These provide early season control, reducing early season competition.

1b. Woolly cupgrass (*Eriochloa villosa* [Thunb.] Kunth.)

Woolly cupgrass is a relatively new and serious weed problem in the states of Iowa, Illinois, Wisconsin and Minnesota. Its spread has increased rapidly in the last 10 to 15 years. This annual grass weed demonstrates biological, biochemical, and morphological characteristics that make it economically damaging and adds to the difficulty in developing effective management strategies. Woolly cupgrass is a prolific seed producer. This seed tends to germinate earlier and at higher populations than many other annual grass weeds. Woolly cupgrass has demonstrated greater tolerance to most herbicides commonly used for control of annual grasses in sweet corn.

1c. Fall panicum (*Panicum dichotomiflorum*)

Fall panicum is a summer annual that grows best in warm, wet, fertile soils. The plant tillers profusely and in late August and September the tillers open and scatter hard-coated seeds. These seeds may remain viable for years. Fall panicum is most often a problem in reduced or no-till fields where undisturbed soils favor germination. Fall panicum has shown some tolerance to atrazine, and can be a serious grass weeds in the region.

1d. Wild proso millet (*Panicum miliaceum*)

Wild proso millet is a summer annual that tends to be more common in no-till fields and in areas where popcorn and sweet corn production are prevalent. Wild proso millet is one of the most competitive grasses in sweet corn; prolific, late season germinator, natural tolerance to the acetamides, spreading west and south. Its seed matures at sweet corn harvest and is then spread by harvest equipment. Its late germination and partial tolerance to the acetamides makes control difficult. Stale bed and crop rotation aid control.

1e. Barnyardgrass (*Echinochloa crusgalli*)

This summer annual germinates from 0 to 4 inches deep in the soil. The seeds remain viable for several years, and plants may emerge throughout the summer. Barnyardgrass is most troublesome in low, moist, warm soils.

1f. Field sandbur (*Cenchrus pauciflorus*, also *C. longispinus*)

Field sandbur is a summer annual weed common in sandy soils. The bur of field sandbur can injure scouts and field workers. It is a significant problem in Havana and Manito area (Central IL sands).

1g. Crabgrass spp. (*Digitaria* spp.)

A warm season grass most often troublesome in the southern region of the Corn Belt as well as sandy irrigated areas in MN, WI, and IL. The plants root at the nodes and due to a high root to shoot ratio may be very competitive where moisture is limiting. May be most severe during the late part of the growing season after herbicides have degraded and/or when holes remain in the canopy. Tillage and row cultivation also help control. It is an increasing problem. Crabgrass is tolerant to nicosulfuron, the only postemergence grass herbicide registered in sweet corn.

1h. Shattercane (*Sorghum bicolor*)

Shattercane is an annual grass that is found primarily in cultivated fields where it reseeds itself. Since all sorghums are members of the same species and can hybridize, shattercane is often found in greater populations where sorghums are grown. It is more prevalent in the southern portion of the Corn Belt. Shattercane outcrosses with other sorghum types and is known for developing resistance to ALS type herbicides.

Non Chemical Control:

- Tillage prior to planting is an important method of annual grass control. Repeated tillage, though not always compliant with conservation tillage practices, may accelerate the reduction of the number of weed seeds from the seed bank in the soil.
- Row crop cultivation is effective in reducing the impact of weed competition but does not remove enough weeds by itself to result in significantly reduced weed seed numbers in the soil.
- Other methods of non-chemical control, such as crop rotation, and adjusting planting dates tends to change the relative mix of species in fields but does not significantly reduce competition from annual weeds overall.
- Field sanitation and the use of certified and clean seed do reduce the spread of many weed species and is always a recommended practice.

Chemical Controls:

Pre-emergence control of annual grasses: As noted in the table below, both pre and post emergence herbicides are used for annual grass control. Four classes of herbicide active ingredients are used pre-emergence; triazines (simazine, atrazine), acetamides (alachlor, metolachlor, dimethenamid,), dinitroaniline (pendimethalin), and thiocarbamates (EPTC, butylate). In addition, glyphosate is sometimes used as a burndown herbicide prior to plant, especially on no-till sweet corn. EPTC and butylate have decreased in use for sweet corn production due to increased use of conservation tillage and the availability of other viable options. Neither of these may be available locally and both have been removed from recommendation guides.

For control ratings of each weed for each listed herbicide or non-chemical management practice see the table at the end of this section.

Note: Resistance management is a consequence of the herbicide rotations and practices used in field corn and soybean weed management since sweet corn is grown in rotation with these crops. The rotational restrictions of some sweet corn herbicides (esp. atrazine and simazine) limit their usefulness because sweet corn growers need to plant other vegetable crops in subsequent years, which are prohibited. Concern over plant back restrictions for sweet corn is especially acute.

Photosystem II inhibitor (Triazines)

Atrazine (Many)

- Enhances tank mix options with grass herbicides but is typically not used as a grass herbicide
- REI- 12hrs PHI-21d

Simazine (Princep)

- Used on sands but is not typically used as a grass herbicide
- REI- 12hrs PHI-NA

Root/shoot inhibitor (Acetamides)

- 42 day residual control
- Lose residual control for wild proso millet, woolly cupgrass, and sandbur

Alachlor (Micro-tech)

- Leaches in soil
- Control = fair to good
- On sands may be phytotoxic to sweet corn

- REI-12hrs PHI- 70d

Metolachlor (Dual II Magnum)

- Level of control = good to excellent
- Product of choice for grass control
- REI-12hrs PHI-70d

Dimethenamid (Outlook)

- Level of control = good to excellent
- REI- 12hrs PHI-50d

Mitosis inhibitor (Dinitroanilines)

Pendimethalin (Prowl/Pentagon)

- Hybrid sensitivity, crop tolerance - brittle stalks
- Good control on wild proso millet
- Lower cost than acetamides
- REI-12hrs PHI-60d

Shoot inhibitor (Thiocarbamates)

EPTC (Eradicane)

- REI-NA PHI-NA
- Probably not available throughout much of region

Butylate (Sutan Plus)

- Probably not available throughout much of region
- REI- NA PHI-NA

EPSP synthase inhibition

Glyphosate (Roundup)

- Used principally for preplant burndown, stale bed, and post plant spot treatments
- Concerns about resistance management as more weeds become resistant
- REI- 4hrs PHI-7d

Post-emergence control of grasses:

For control ratings of each weed for each listed herbicide or non-chemical management practice see the table at the end of this section.

ALS inhibitors (Sulfonylureas)

Nicosulfuron (Accent)

- Limited to use on selected hybrids of processed sweet corn
- OP interactions causes crop injury
- Weed resistance with foxtails, shattercane, inherent tolerance of crabgrass
- REI- 4hrs PHI-45d

2. Perennial grasses and grasslike weeds

Biology and Life Cycle:

- Although perennial grasses and nutsedges produce seed each year the primary mechanism of reproduction is through vegetative propagation.
- Tillage can be an effective mechanism of controlling perennial grasses but when done improperly may further distribute the weed throughout the field and exacerbate the problem.
- Quackgrass is a cool weather plant and grows aggressively early in the spring and in the fall. The other perennials listed tend to grow more actively during the late spring and summer.

Pest Distribution and Importance:

- Perennial grasses were once a severe problem in sweet corn production prior to herbicides and when pasture was a standard part of the crop rotation. With the introduction of effective herbicides and decline in pasture rotations, many perennial grasses have declined in importance.

2a. Quackgrass (*Elytrigia repens*)

Quackgrass is a perennial grass that spreads by rhizomes. These rhizomes are effectively spread by tillage, increasing the distribution of the population in a field. Tillage is an effective control by depleting food reserves and bringing rhizomes to the surface. Overall this weed is decreasing in importance.

2b. Wirestem muhly (*Muhlenbergia frondosa*)

Wirestem muhly is a perennial grass that reproduces by seeds and underground rhizomes. It is native to the Midwest. It was not considered a common row crop weed until the 1950's when serious infestations developed in cultivated fields. Delayed seedbed preparation will help control wirestem muhly in sweet corn by bringing rhizomes to the soil surface to dry out. This weed is on the increase.

2c. Johnsongrass (*Sorghum halepense*)

Johnsongrass produces large rhizomes that can be spread throughout the field making it difficult to contain and control. Johnsongrass is more common in the southern portions of the Corn Belt and is a serious problem south of I-70. Johnsongrass is also a reservoir for Maize Dwarf Mosaic Virus.

2d. Yellow Nutsedge (*Cyperus esculentus*)

Yellow nutsedge causes the most severe perennial weed infestations and is quite serious across the region. It reproduces from tubers as the seed does not survive overwintering, and tubers can adapt to almost any soil type and conditions. Tubers germinate at depths of up to 12 inches and may remain viable for up to three years in many soils.

Non Chemical Control:

- Tillage prior to planting tends to reduce the growth of some perennial weeds that germinate early (i.e. nutsedge). Repeated tillage, though not always compliant with conservation tillage practices, is sometimes the only effective method of perennial weed control.
- Row crop cultivation may also impact perennial weeds and reduce weed competition.
- Other methods of non-chemical control, such as crop rotation with perennial crops, and adjusting planting dates can seldom be used in the Midwest.
- Field sanitation does reduce the introduction of some perennial weed species and is always a recommended practice.

Chemical Controls:

Pre-emergence control of perennial grasses: Suppression of nutsedges, and perennial grasses is effected with the use of EPTC or butylate, where available. In addition, nutsedge can be suppressed by the acetamide herbicides. Roundup can also be used if the grasses are present in the field and growing prior to planting or if the grasses are actively growing after the crop is removed. For quackgrass, nutsedge, and Johnsongrass, tillage is useful.

For control ratings of each weed for each listed herbicide or non-chemical management practice see the table at the end of this section.

Shoot inhibitor (Thiocarbamates)

EPTC (Eradicane)

- Not generally available
- Doesn't have good perennial activity
- REI-12hrs PHI-used at planting

Butylate (Sutan Plus)

- Not generally available
- Doesn't have good perennial activity

- REI-12hrs PHI-used at planting

EPSP synthase inhibition

Glyphosate (Roundup)

- Must be applied postemergence, either before planting or after harvest.
- REI- 4hrs   PHI- used before planting

Post-emergence control of nutsedge and perennial grasses: Post emergence and perennial grass control is generally achieved by the use of nicosulfuron. As indicated below, specific products may cause crop injury and may not be used where certain OP insecticides have been applied. Nutsedge may be controlled by halosulfuron, bentazon, or bentazon plus atrazine.

For control ratings of each weed for each listed herbicide or non-chemical management practice see the table at the end of this section.

ALS inhibitors (Sulfonylureas)

Halosulfuron (Permit, Sandea)

- Level of control = Good on Nutsedge
- Significant risk of crop injury depending on hybrid
- OP interaction causes crop injury
- REI = 12hrs PHI =30d

Nicosulfuron (Accent)

- Limited to processed sweet corn
- Crop injury risk depending on hybrid
- OP interaction results in crop injury
- REI- 4hrs   PHI-45d

Photosynthetic inhibitor

Basagran (Bentazon)

- Mainly nutsedge control
- No perennial grass activity
- Good crop safety
- REI-12hrs PHI-30d

3. Annual broadleaf weeds

Biology and Life Cycle:

- Broadleaf weeds germinate at soil depths from 1/8th of an inch to 3 or 4 inches. Seed size and dormancy are the controlling factors for when and where these seeds emerge. Large seeded broadleaf weeds have greater seed food reserves and can emerge from greater soil depths where moisture is less variable than near the soil surface.
- Weeds germinate at various times throughout the season depending on environmental cues such as moisture availability and soil temperature.
- Weeds produce prolific numbers of seeds which may lie dormant for very brief (2 weeks) or very long (30-50 yrs) periods before germination.
- Weed seeds are distributed by wind, rain, birds, and mechanical harvesting equipment.

Pest Distribution and Importance:

- Each of the weeds listed below has its own distribution range and importance.
- The importance of various weeds is highly dependent upon the prevailing attitudes and herbicide use practices. As herbicide use patterns change weed species change as well.

3a. Eastern Black Nightshade (*Solanum ptycanthum*) & **Hairy nightshade** (*S. sarrachoides*)

This summer annual can produce thousands of berries; each berry contains up to 50 seeds. While nightshade is generally not considered a serious pest in the Corn Belt, severe infestations in individual fields do occur. Tillage and row cultivation are effective for early, newly emerged seedlings.

3b. Common Cocklebur (*Xanthium strumarium*)

Common cocklebur is a summer annual weed. Its seeds are spread by attaching to animal fur or by tillage or harvesting equipment. Cocklebur is a serious competitor for moisture. Cultivation and tillage will all help to control cocklebur establishment.

3c. Common Lambsquarters (*Chenopodium album*)

Common lambsquarters produce numerous small seeds which germinate after an overwintering process. Optimal temperature for germination is 70F, but can germinate between 40 to 94, which suggests early germination capabilities. Survival is favored by rains that dilute or leach herbicides from the soil surface.

3d. Common Ragweed (*Ambrosia artemisiifolia*)

Common ragweed is a summer annual that is favored by moist soils and can be a serious problem in individual fields. Control of common ragweed with tillage or row cultivation is effective in controlling small seedlings. More serious in sands

3e. Giant Ragweed (*Ambrosia trifida*)

Wet weather favors giant ragweed, and this summer annual may be a severe problem in isolated fields. The seeds of giant ragweed may remain viable in the soil for several years. Small seedlings can be controlled with row cultivation and tillage. This weed is more serious in sands.

3f. Jimsonweed (*Datura stramonium*)

Jimsonweed produces several hundred hard-coated seeds per plant that may remain viable in the soil for years. This summer annual grows best under warm temperatures and moist soils. Jimsonweed infestations harm soybean crops via competition for water, especially in dry years. The shade of its leaves in shorter crops increases yield loss due to decreased nutrient uptake. Jimsonweed also contains the alkaloids, atropine, hyoscyamine, and hyoscine, which are toxic. Even small amounts of jimsonweed can cause harvest problems.

3g. Kochia (*Kochia scoparia*)

Kochia is similar to common lambsquarters in many respects. It produces numerous small seeds and can germinate early in the season. Kochia has also developed resistance to a number of herbicides including triazines and ALS compounds. Although not distributed as widely as lambsquarters, kochia has been expanding from small infestations started along rail and road systems where seed has been carried in.

3h. Morningglories (*Ipomoea* spp.)

Tall morningglory and ivyleaf morningglory are the two major annual morningglory species found in the Corn Belt. The seeds of these summer annuals may survive for several years in soil. Infestations are most common in moist soils along river bottomland, but these plants can be found mid-IL and south. Annual morningglories adapt to crops by vining about the crop, so shading by the canopy is not particularly successful in reducing growth. Newly emerged seedlings can be controlled by tillage and cultivation, but this may result in conditions that favor emergence by weeds deeper in the soil profile. After vines begin to twine about the stems of the crop, cultivation may not be as effective.

3i. Pennsylvania Smartweed (*Polygonum pensylvanicum*)

This summer annual grows best on wet soils and is widely distributed across the Midwest. Smartweed emerges early in the spring and can be a severe problem if tillage is delayed to wet soils, as seedbed preparation may result in transplanting larger plants rather than destroying them.

3j. Pigweeds (*Amaranthus retroflexus*, *A. hybridus*, *A. powellii*)

Pigweeds are prolific seed producers, and one plant can produce over 100,000 seeds in one growing season. The seeds of this plant may remain viable for years. Pigweeds are a problem in no-till systems because undisturbed soils favor germination of the minuscule seeds, and the debris keeps the field moist and allows for extended germination. Other favorable germination locations are where excess nitrogen is available, and where no soil applied herbicides have been used. Localized populations of some biotypes of pigweed have shown triazine or acetolactate synthase (ALS)-inhibitor resistance.

3k. Velvetleaf (*Abutilon theophrasti*)

Velvetleaf is the most significant annual broadleaf weed in most sweet corn production and is most damaging in the central part of the region. Velvetleaf is a serious competitor for moisture in drought conditions. Cultivation can partially control velvetleaf when used in the early season.

3l. Waterhemp (*Amaranthus tuberculatus*, *A. rudis*)

Common waterhemp is a native species and is a serious weed problem throughout the Corn Belt. Changes in agricultural practices that favor this weed include reductions in tillage, herbicide selection, simplified crop rotations, and recent weather patterns. There are also many indigenous factors that have contributed to the increase in common waterhemp populations. These include seedling emergence late in the growing season, high seed production and an ability to germinate from shallow soil depths. Control of common waterhemp has become increasingly difficult due to resistance to many common herbicides. Waterhemp has demonstrated cross-resistance to herbicides with the ALS inhibition mode of action, as well as to triazine compounds. Waterhemp is perhaps the most serious weed of this group in terms of difficulty to control and overall impact on crop yields.

Non Chemical Control:

- Tillage prior to planting is an important method of annual broadleaf control. Repeated tillage, though not always compliant with conservation tillage practices, may accelerate the reduction of the number of weed seeds from the seed bank in the soil.
- Row crop cultivation is effective in reducing the impact of weed competition but does not remove enough weeds by itself to result in significantly reduced weed seed numbers in the soil.
- Other methods of non-chemical control, such as crop rotation, and adjusting planting dates tends to change the relative mix of species in fields but does not significantly reduce competition from annual weeds overall.
- Field sanitation and the use of certified and clean seed do reduce the spread of many weed species and is always a recommended practice.

Chemical Controls:

Pre-emergence control of annual broadleaf weeds:

Soil applied herbicides need to be in place and evenly distributed throughout the top 1 to 2 inches of soil at the time of weed emergence for adequate uptake and maximum effect. Under conditions of high rainfall many pre-emergence herbicides may be too diluted or leached out of this soil zone and rendered ineffective. Under very dry conditions, pre-emergence herbicides may not have been leached into the soil far enough to have the substantial contact necessary for weed death.

Large seeded broadleaf weeds like velvetleaf and giant ragweed are difficult to control with preemergence herbicides. Other broadleaf weeds produce small seeds, such as pigweeds, lambsquarters, kochia, and nightshade. Many of these weeds germinate throughout the season in response to soil wetting provided by occasional rainfall. Pre-emergence herbicides, which have short soil persistence, may not adequately control the late flushes of germinating weeds.

For control ratings of each weed for each listed herbicide or non-chemical management practice see the table at the end of this section.

Photosystem II inhibitor (Triazines)

- Resistance management problems - 4-5 weeds have been identified as resistant already

Atrazine (Many)

- At current use rates does not provide season long broadleaf control
- Atrazine rates are restricted to below federal use rates in some Wisconsin areas
- Enhances tank mixes, provides consistency in tank mix

- High frequency of use, especially after loss of Bladex
- REI- 12hrs PHI-21d

Simazine (Princep)

- Mainly used for sandbur control
- Rotational restrictions limit is use
- REI- 12hrs PHI-used at planting

Root/shoot inhibitor (Acetamides)

- Contributes to control of some small seeded broadleaf weeds, not principally broadleaf herbicides

Alachlor (Micro-tech, Lasso)

- REI-12hrs PHI-used at planting

Metolachlor (Dual II Magnum)

- REI-12hrs PHI-used at planting

Dimethenamid (Outlook)

- REI- 12hrs PHI-used at planting

Mitosis inhibitor (Dinitroanilines)

Pendimethalin (Prowl/Pentagon)

- Not principally a broadleaf herbicide but contributes to control
- Better control of lambsquarters than acetamides
- Crop tolerance is marginal
- REI-12hrs PHI-used at planting

Post-emergence control of annual broadleaf weeds:

As mentioned above, several flushes of broadleaf weeds can occur throughout the season. Although there are no post-emergence broadleaf herbicides with true "residual" activity some herbicides do provide a modicum of control through soil activity. These herbicides include post applications of atrazine. Though the trend for increasing use of post applied herbicides continues, concerns about crop injury and drift to off-target crops or plants remains a hindrance. A new product and new chemistry is Callisto (mesotrione). Since it is newly registered for field corn less is known of the advantages and disadvantages for sweet corn other than it has potential for broadleaf weed control. However, new chemistries are always welcome from the perspective of managing resistant weed development.

For control ratings of each weed for each listed herbicide or non-chemical management practice see the table at the end of this section.

Growth Regulator

-

2,4-D (Many)

- Crop tolerance limits its use
- Export restrictions limit its use
- Used mainly as a burndown
- Some formulations have better safety tolerance
- REI-48hrs PHI-45d

ALS inhibitors (Sulfonylureas)

- OP interactions
- Resistance problems with waterhemp, ragweeds, kochia

Nicosulfuron (Accent)

- Limited broadleaf spectrum
- Crop injury may occur
- REI- 4hrs PHI-45d

Halosulfuron (Permit, Sandea)

- Limited Broadleaf spectrum, not effective on lambsquarters or nightshade
- Good on velvetleaf, pigweeds, ragweeds
- Not effective on lambsquarters
- Crop injury may occur
- REI-12hrs PHI- 30d

Photosystem II inhibitors

Bentazon (Basagran, in Laddok)

- Level of Control = Good on velvetleaf and cocklebur
- When combined with atrazine its good on broad spectrum of broadleaf weeds
- REI-12hrs PHI-30d

PPO Inhibitor

Carfentrazone (Aim)

- Control of velvetleaf is excellent
- Control of pigweeds, nightshade is good
- Risk of crop injury
- REI-12hrs PHI-

EPSP synthase inhibition

Glyphosate (Roundup)

- Used for burndown preplant or stale seedbed treatment
- Spot treatment label
- Resistance management concerns
- REI-4hrs PHI-used before planting or after harvest

4. Perennial broadleaf weeds

Biology and life cycle:

- While perennial weeds do produce seeds, the majority of plants listed propagate through vegetative means.
- Most perennial weeds begin growth early in the season before crops are planted and may also have a very active period of growth after the crop has been harvested.
- Tillage can be effective for controlling many perennial weeds but it may also distribute viable rhizomes, roots, and tubers throughout the field if done improperly.

Pest Distribution and Importance:

- The occurrence of perennial broadleaf weeds is highly dependent on the tillage regime used in sweet corn production. Since most perennial broadleaf weeds do not tolerate tillage, these weeds are more of a problem in reduced tillage and no-till operations.

4a. Common Milkweed (*Asclepias syrica* L.)

This perennial weed reproduces by seeds and adventitious buds that sprout from underground roots. Seedlings produce vegetative buds 18-21 days after germination, and seeds may remain viable for up to three years. Seeds may germinate from as deep as 2 inches in the soil, and undisturbed fields or fields with reduced tillage and moist soils are favored. Problems with common milkweed have been increasing due to the decrease in tillage and row cultivation.

4b. Canada thistle (*Cirsium arvense*)

Canada thistle is a perennial weed with a vigorous, rhizome-like root system. Propagation is by rootstock and seeds; only female plants produce seed. Preplant tillage and row cultivation can control small seedlings but are less effective in controlling plants arising from rootstocks.

4c. Field bindweed (*Convolvulus arvensis*) and hedge bindweed (*Calystegia sepium*)

These weeds are vining weeds commonly found in both cultivated and no-till fields. These weeds can rapidly engulf sweet corn rows in vines reducing sweet corn growth and yield. The extensive mass of vines also makes harvest very difficult.

4d. Hemp dogbane (*Apocynum cannabium*)

This perennial weed is capable of regrowth from perennating rootstock within six weeks of emergence. The underground root system may extend laterally 20 feet per year and downward as far as 14 feet. The central portion of the Corn Belt is usually most severely infested with dogbane. Tillage can reduce dogbane infestations, but is ineffective once populations are established.

4e. Swamp smartweed (*Polygonum coccineum* Muhl. ex Willd)

Swamp smartweed is commonly found in low, wet areas of fields. Because of an extensive root system it is a strong competitor with sweet corn and difficult to eradicate. Because of it's similarity to Pennsylvania smartweed, an annual, many producers incorrectly identify this weed.

4f. Bigroot Morningglory (*Ipomoea pandurata*)

Bigroot morningglory is becoming more common. It produces a tuber that can reach eight inches in diameter and several feet deep. When the new vines emerge they are purplish in color. Control almost invariably will require many repeated treatments. A very serious problem in Wabash Valley.

4g. Pokeweed (*Phytolacca americana*)

Pokeweed is becoming more important as a weed throughout the eastern section of the Corn Belt. It tends to be hard to kill.

4h. Horsenettle

Horsenettle is on the increase due to an increase of minimal tillage. Becomes a rotational problem with other vegetable crops. It is a reservoir for viruses in other vegetables.

4i. Dandelion

Difficult to control with burndown treatments in reduced tillage.

Non Chemical Control:

- Tillage prior to planting tends to reduce the growth of some perennial weeds that germinate early. Repeated tillage, though not always compliant with conservation tillage practices, is sometimes the only effective method of perennial weed control.
- Row crop cultivation may also impact perennial weeds and reduce weed competition.
- Other methods of non-chemical control, such as adjusting planting dates, can seldom be used.
- Field sanitation does reduce the introduction of some perennial weed species and is always a recommended practice.
- Timing is critical, if done improperly tillage may result in the spread of rhizomes or root stock and proliferate the problem
- Tillage opens up soil on heavy soils. Moldboard plow is an option in some instances that will help control weeds.
- What weed species are present depends on rotation regimes within area where sweet corn is planted.

Chemical Controls:

Pre and Post emergence control of perennial broadleaf weeds: While much of the effort to control perennial weeds takes place before the crop is planted or after it has been harvested, effective control of perennial weeds often necessitates control efforts during the cropping season as well. The control ratings for some of the more common perennial broadleaf weeds are included in a table at the end of this section. Other perennial broadleaf weeds than those listed above, such as Jerusalem artichoke may also be present in some fields, but are less prevalent.

The control ratings given for perennial weeds tend to be more subjective than those for annual weeds. For example, although a rating of “Good” for control of an annual weed typically suggests 85 percent or better control of a weed, a rating of “Good” for perennial weeds might indicate anywhere from 60% to 90% dieback. The variability in rating perennial weeds arises from the fact that there are fewer studies to determine control, there are fewer products and control measures available with which to compare, and that perennial weeds typically re-sprout from root stock soon after dieback. It is generally agreed that multiple treatments in a season, which include a combination of herbicides and mechanical means of control, are necessary to reduce perennial weed populations and obtain what is otherwise termed "Good" control. It is also difficult to get good control of perennial broadleaf weeds because herbicides can not be applied at optimal stage of growth.

EPSP synthase inhibition

Glyphosate (Roundup)

- Level of Control = Fair for common milkweed control, hemp dogbane, and swamp smartweed
- Level of Control = Good for Canada thistle and field bindweed control
- Spot treatment, burndown preplant, or stale bed only
- Marginal on dandelion for burndown treatments
- REI- 4hrs PHI-used before planting or after harvest

Growth Regulator

2,4-D (Many)

- Burndown (preplant only) due to crop sensitivity
- Level of Control = Marginal at labeled rates
- REI-48hrs PHI-45d

Photosynthetic inhibitors

Bentazon (Basagran, in Laddok)

- Level of Control= Fair for some species, may have to treat more than once
- REI-12hrs PHI-30d

5. Winter Annual Weeds and Cover Crops

Biology and life cycle:

- Winter annual weeds start their growth in the fall and complete their life cycle in the spring, often bearing seed in May or June. While discing, plowing, or field cultivation tillage is effective for all winter annuals, no-till and conservation tillage fields must rely on herbicides for control.
- Heavy populations of winter annual weeds can sap the moisture from the soil and slow or reduce germination of the crop.

Pest Distribution and Importance:

- A number of winter annual weeds can be present in fields throughout the Midwest with the most common of these being henbit and chickweed.
- Some winter annuals are more prevalent across the northern portion of the Corn Belt, while others such as annual bluegrass and annual brome-species tend to be more of a problem across the southern section of Missouri, Illinois, Indiana and Ohio.
- Weeds present in the field early in the season may attract damaging insects and provide an environment for egg laying.

5a. Common Chickweed (*Stellaria media*)

A common weed which produces prolific amounts of seed and a thick mat of low vegetative growth. Can remove much soil moisture and, if untreated, can seriously affect crop establishment and growth in dry years.

5b. Horseweed (Marestail) (*Conyza canadensis*)(previously *Erigeron canadensis*)

This weed is becoming much more common throughout the Midwest due to reduced tillage. It produces a large amount of seed that is wind borne. Resistant biotypes of this weed to glyphosate have been identified. Reservoir of viruses.

5c. Henbit (*Lamium amplexicaule*)

This plant is a low growing (5 to 9 inches) winter annual. It can produce a thick mat of growth early in the season and pull needed moisture from the soil.

5d. Mustards

Mustard species include field pennycress (*Thlaspi arvense*), wild mustard (*Brassica kaber*), tansy mustard (Descurainia pinnata), shepherd's-purse (Capsella bursa-pastoris), yellow rocket (*Barbarea vulgaris*), and the pepperweeds (*Lepidium* spp.) Although a number of herbicides may control some mustard species, the presence of mature (large) mustards in the fields early in the season often limits which herbicides may be applied. Though usually less aggressive than henbit and common chickweed in terms of population expansion, they are serious competitors with crops.

5e. Brome grasses (*Bromus* spp.)

Brome grasses include downy brome, Japanese brome, and cheat. If left uncontrolled these grasses will continue to pose a competitive threat to the crop.

5f. Bluegrass (*Poa annua*)

Bluegrass can become more of a problem under continuous no-till. Although populations do not grow at an explosive rate, control without tillage can be difficult.

5g. Grass Cover Crops

Grass cover crops include winter annual grains planted to protect the soil and build soil tilth and at times, more established sods from conservation plantings being converted to cropland. The former may include barley, rye, and wheat while the latter may include ryegrass, orchardgrass, perennial bromegrasses, fescue and timothy.

Non Chemical Control:

- Tillage prior to planting effectively eliminates competition from winter annual weeds. However, tillage is not always compliant with conservation tillage practices.
- Tillage opens up soil on heavy soils. Moldboard plow is an option in some instances that will help control weeds.
- What weed species are present depends on rotation regimes within area where sweet corn is planted.

Chemical Controls:

The following herbicides are commonly used for burndown of winter annual weeds or cover crops. Various combinations of these products may be used depending on the weed species present and the size of the weeds.

Photosystem II inhibitor (Triazines)

Atrazine (Many)

- REI- 12hrs PHI-21d
- Level of Control = good

Simazine (Princep)

- Level of Control = fair to good
- REI- 12hrs PHI-used before planting

EPSP synthase inhibition

Glyphosate (Roundup)

- Burndown and preplant only
- Horseweed (marestail) resistance is becoming common
- REI-4hrs PHI-used before planting or after harvest

Growth Regulator

2,4-D (Many)

- Preplant and burndown only
- REI-48hrs PHI-45d

Photosystem I

Paraquat (Gramoxone Max)

- Burndown only
- REI - 48 hrs PHI-used before planting

6. Herbicide Resistant Weeds

A number of weed biotype populations have been identified as having resistance to one or more herbicide classes. Those most commonly found are **waterhemp, lambsquarters, kochia, and pigweeds**. In addition, resistant biotypes of **common and giant ragweed, cocklebur, shattercane, velvetleaf**, **horseweed (marestail)** and **giant foxtail** have been found in some areas. The herbicide modes of action that have resulted in the most rapid development of resistant populations include those that have been used with the greatest frequency for weed control in corn and soybeans. This would include the triazines (translocated photosynthetic inhibitors) and the ALS inhibitors (sulfonylureas and imidazolinones). There is considerable concern about the potential development of resistance to glyphosate as it also has become widely used within the last 5 years. Both horseweed and waterhemp have shown resistance to glyphosate in the Midwest.

The difficulty in dealing with herbicide resistant weeds is often that the presence of such weeds necessitates the use of a more robust and more expensive approach to weed control. Since whole groups of compounds are no longer effective many individual products within those groups will no longer be efficacious. Control often rests on a strategy of crop rotation (to permit rotation of herbicides) and herbicide combinations.

The development of resistant weed biotypes can be delayed or postponed indefinitely through the proper selection of herbicides, tillage, and equipment and field sanitation.

Resistance management is mainly a field corn and soybean issue. **See notes previous.**

Table 2. Estimates[4] of Crop Loss and % Crop Area Infested by Weeds

Weed Name	Scientific Name	% Acres Infested at any level	% Loss* on area infested	Avg Loss%
Barnyardgrass	Echinochloa crusgalli	15	4.5%	0.675
Eastern black nightshade	Solanum ptycanthum	30	0.7%	0.21
Common cocklebur	Xanthium strumarium	50	0.5%	0.25
Common lambsquarters	Chenopodium album	90	1.8%	1.62
Common milkweed	Asclepias syrica .	10	11.9%	1.19
Common ragweed	Ambrosia artemisifolia	60	0.5%	0.3
Crabgrass	Digiteria spp.	60	0.5%	0.3
Fall panicum	Panicum dichotomiflorum	60	3.2%	1.92
Foxtail species	Setaria spp.	95	0.6%	0.57
Giant ragweed	Ambrosia trifida	70	5.2%	3.64
Jimsonweed	Datura stramonium	40	0.5%	0.2
Morningglory	Ipomoea spp.	40	0.5%	0.2
Pigweed spp.	Amaranthus spp.	90	0.5%	0.45
Shattercane	Sorghum bicolor	20	1.1%	0.22
Velvetleaf	Abutilon theophrasti	60	5.6%	3.36
Wild proso millet	Panicum miliaceum	30	2.5%	0.75
All Weeds				15.855

Table 3. Estimates[4] of Herbicide Application rate and area treated for 2003.

Herbicide	Area Applied (%)	Rate/ Application (Lbs/acre)
Atrazine	95	1.07
Metolachlor	35	2.14
Alachlor	10	2.06
Dimethenamid	40	1.17
Bentazon	15-20	.44
Glyphosate	1-5	.51
Nicosulfuron	25-45	.03
2,4-D	10	.35
Simazine	1	1.39
EPTC	<1	3.0
Butylate	<1	4.0
Carfentrazone	25 -45	.008

Table 4. Herbicide Rates, MOA, REI, PHI and Primary Target

Trade Name	Common Name	Product rates low......hi	Unit rate	MOA	REI hrs	PHI days	Primary Target
Preemergence							
AAtrex 4L	atrazine	3.2---4	pt		12	21	
AAtrex Nine-O	atrazine	1.8---2.2	lb		12	21	
Dual Magnum	s-metolachlor	1.0---3	pt			70	Grass/BL
Eradicane Extra 6.7EC	EPTC+safener +extender	4---8	pt		12	70	Grass/BL
Outlook 6EC	dimethenamid	10---21	fl oz		12	50	Grass/BL
Lasso 4EC	alachlor	2---4	qt		12	70	Grass/BL
Prowl 3.3EC	pendimethalin	1.2---3.6	pt		24	70	Grass/BL
Sutan 6.7EC	butylate+safener	2.5---3.5	qt			70	Grass
Postemergence							
2,4-D amine	2,4-D	0.5---1	pt		48	45	BL
AAtrex 4L	atrazine	1---1.5	pt		12	21	
AAtrex 80WP	atrazine	0---1.8	lb		N/A	21	
AAtrex Nine-O	atrazine	0---1.6	lb		12	21	
Accent 75SP	nicosulfuron	0---0.6	oz			45	Grass/BL
Basagran 4S	bentazon	1.5---2	pt		12	30	BL
Stale seedbed							
Roundup Ultra	glyphosate	1.5---2	pt		4	80	Grass/BL

Insect Pests

The most important pests in sweet corn cause damage to ears; European corn borer, corn earworm, western bean cutworm, and fall armyworm. An early season pest is the black cutworm, although cutworm infestations tend to be more sporadic than the ear-invading pests. The corn flea beetle can be a problem on some hybrids, as a vector of Stewart's bacterial wilt early in the season (5).

Corn grown under contract for processing has allowable damage of 5-20% of the ears, depending on the severity, before grade is lowered. Fresh market sweet corn has a much lower tolerance for damage; fewer than one out of twenty ears (<5%) arriving at the point of sale can exhibit injury. Most contract growers depend heavily on crop scouting and monitoring traps, both pheromone and blacklight, to aid in decision making regarding insecticide application. In a typical year, the major insect pests cause severe economic damage on 15% or more of the total acreage. There are several types of injury inflicted by these pests and occurrence and damage severity can vary significantly by year and region. Insect resistance to insecticides is an ever-present issue.

European Corn Borer is probably the most significant pest of sweet corn in the North Central States production area. Corn earworm is the target of repeated pesticide applications throughout the growing season and is associated with resistance management techniques in sweet corn. However, migratory insects from cotton and (perhaps) field corn insecticide treatments may be the major source of resistance concern. As mentioned previously, planting dates are often staggered to permit market delivery of sweet corn over a greater length of time. Altering planting dates may also improve insect pest management but it is not practical due to market window demand.

Table 5. Estimates[4] of Crop Loss and % of Area Infested by Insects

Common Name	Scientific Name	% Acres Infested*	% Loss on infested area*	Avg loss %
Black Cutworm	Agrotis ipsilon	5	35	1.7
Corn Earworm	Helicoverpa zea	4 50 **	90 25	3.6 12
Corn Leaf Aphids	Rhopalosiphum maidis	12	15	1.8
Corn Rootworm, Northern	Diabrotica barberi			0
Corn Rootworm, Western	Diabrotica virgifera	>1	95	0.4
European Corn Borer	Ostrinia nubialis	2 70**	100 10**	2.2 7**
Fall Armyworm	Spodoptera frugiperda	2	66	1.4
Flea Beetles	Disonycha triangularis			0
Japanese Beetle	Popillia japonica			0
Sap Beetle	Carpophilus lugubris (Murray)			0
All insects				11

*Based on U.S. Averages

** Fresh market estimation

Germination and emergence

1. Seedcorn maggot (*Delia platura*)

Biology and Life Cycle:

- The seedcorn maggot is the larva of a small fly. The flies are attracted to fields where relatively fresh animal manure, green manure and other organic material are present.
- Seedcorn maggots seek out germinating soybean and corn seeds and eat the germ, killing the plant.
- Rescue treatments are not available for control of seedcorn maggot. Therefore, most treatments are made in anticipation of problems or replant situations.

Pest Distribution and Importance:

- Overall, seedcorn maggots are considered a minor pest in corn production.
- This pest tends to be 'spotty' in an infested field.
- Growers may be controlling seedcorn maggot with soil insecticides applied for rootworm, wireworms, etc.

Chemical controls:

Organophosphate + Organochlorine

Lindane+diazinon (Kernel Guard, Agrox, others) as a seed box treatment

- Level of control = Good
- REI-48hrs PHI= Not applicable to soil/seed treatments

Organophosphate

Terbufos (Counter)

- Level of control = Good
- REI- PHI= Not applicable to soil/seed treatments

Chlorethoxyfos (Fortress)

- Level of control = Good
- REI- PHI= Not applicable to soil/seed treatments

Organophosphate + pyrethroid

Tebupirimphos+cyfluthrin (Aztec)

- Level of control= Good
- REI- PHI=Not applicable for soil/seed treatment

Carbamates

Carbofuran (Furadan)

- Level of control = Good
- REI- PHI=Not applicable for soil/seed treatment

Pyrethriods

Tefluthrin (Force ST)

- Level of control= Good
- REI- PHI=Not applicable for soil/seed treatment

Bifenthrin (Capture)

- Level of Control= Good
- REI- PHI=Not applicable for soil/seed treatment

Tefluthrin (Force 3G)

- Level of control = Good
- REI- PHI=Not applicable for soil/seed treatment

Neonicotinoids

Imidacloprid (Gaucho, Gaucho Extra, and Prescribe)

- Level of control= Good
- REI - PHI=Not applicable for soil/seed treatment

Other Pest Management aids:

- Later planting may accelerate crop growth and help avoid damage but is usually not a practical solution.
- Field sanitation techniques, such as clean tillage may help to reduce insect damage, but is usually not a practical solution.

Pipeline Pest Management Tools:

- Other neonicotinoids are under development

"To do" List

None listed

2. True white grub [*Phyllophaga* sp.], **wireworm** [*Melanotus* sp.], **Japanese beetle grub [**Popillia japonica**]**, **grape colaspis**, **Seed Corn Beetle**

Biology and Life Cycle:

- These insects attack the germinating corn seed or feed on roots.
- Generally, infestations are patchy in fields and depending on species, damage may recur in succeeding years.
- Rescue treatments are not available for control of these pests, therefore most treatments are made in anticipation of problems or replant situations.

Pest Distribution and Importance:

- These pests are of moderate importance to sweet corn production, though they are becoming more prevalent.
- Wireworms are perceived by producers to be more of a problem west of the Missouri River and in the Wabash Valley.
- White grubs have historically been worse after sod and may be more of a problem where forages are included in rotation with corn (species dependent).
- White grubs tend to be more problematic in earlier planted corn and control is dependent on the number of grubs present.
- White grubs have a three year life cycle and are harder to control in the more mature stages (3rd yr) year.

- Annual white grubs rarely cause economic damage to sweet corn

Chemical controls:

Organophosphate

Terbufos (Counter)

- Level of control = Good
- REI- PHI=Not applicable for soil/seed treatment

Chlorethoxyfos (Fortress)

- Level of control= Good
- REI - PHI=Not applicable for soil/seed treatment

Chlorpyrifos (Lorsban)

- Level of control= Good
- REI- PHI-35d

Organophosphate + Organochlorine

Lindane+diazinon (Kernel Guard)

- Seed box treatment
- Level of control = Good
- REI- PHI=Not applicable for soil/seed treatment

Pyrethriods

Permethrin (Kernel Guard Supreme)

- Level of control = Good
- REI- PHI=Not applicable for soil/seed treatment

Tefluthrin (Force 3G)

- Level of control = Good
- REI- 0hrs PHI=Not applicable for soil/seed treatment

Bifenthrin (Capture)

- Level of control= Good
- REI- PHI=Not applicable for soil/seed treatment

Neonicotinoids

Imidacloprid (Gaucho, Gaucho Extra, and Prescribe)

- Level of control= Good
- REI- PHI=Not applicable for soil/seed treatment

Other Pest Management aids:

- Good grass weed control reduces wireworm problems
- Field sanitation has little effect for these insects

Pipeline Pest Management Tools:

- Neonicotinoids - still in research phase
- Cruiser (thiamethoxam) as seed treatment

“To do” List

None listed

Vegetative stages

3. Corn rootworm (western [Diabrotica virgifera virgifera**] and northern [**D. Barberi**])**

Biology and Life Cycle:

- Adults feed on silks, sometimes inhibiting pollination, and lay eggs in late summer and early fall which hatch in early June of the following year. Corn rootworm (CRW) larvae feed on a narrow range of host species. In general, a corn-soybean rotation disrupts their life cycle and constitutes the most effective management tool available for many farmers.
- Larvae are the most destructive stage of the corn rootworm. Larvae overwinter in soil and begin to develop in the spring, going through three instars while feeding on corn roots. Corn rootworm larvae prune the roots by chewing on the root surface and by tunneling inside during the summer months.

- The corn rootworm complex has two species which are significant to corn production in the Midwest: Northern corn rootworm (D. barberi Smith & Lawrence), and Western corn rootworm (D. virgifera virgifera).
- Some populations of NCR have shown a life cycle adaptation called extended diapause. Extended diapause occurs when some of the eggs rest through the next summer and hatch the second spring after being laid. With extended diapause, control by a corn-soybean rotation can fail. This is currently occurring in parts of Minnesota, Iowa, South Dakota, Illinois, Indiana, (and to a lesser extent) Michigan and Ohio, and has resulted in a change in the dynamics of insecticide use in those areas.
- Recently, populations of WCR have lost a preference to lay eggs in corn, and prefer to lay eggs in other non-corn crop fields, such as soybean. This phenomenon occurs in northern (near the Wisconsin border) and east-central Illinois, northern Indiana, northwestern Ohio, and in southern Michigan.
- With WCR soil-applied insecticide treatments are generally a standard practice in corn acreage following corn and non-corn crops that target the larvae.
- A corn-soybean rotation may fail to control rootworms when volunteer corn plants in a soybean field attract egg-laying beetles.

Pest Distribution and Importance:

- This pest has significant importance to corn production.
- Rootworm tolerant transgenic hybrids may become available in near future, but are targeted to control only rootworms. As a result, they may not reduce the overall perceived risk of insect complexes and associated pesticide use.
- Rootworm insecticides are applied in furrow or in bands. Rootworms survive in the untreated areas, therefore allowing part of the field to remain untreated has relieved the resistance problems. Foliar broadcast applications targeted against adult rootworms have been used in the western Corn Belt in addition to in-furrow or band applications.
- <10% acres treated, some economic loss when populations are high
- Western corm rootworm variant causing problems - adults laying eggs in soybeans (rotational crop for nitrogen supplier) There are also documented cases after wheat and alfalfa
- Sweet corn has a weaker root system so CRW causes more problems than in field corn
- Adult beetle also clips silks, later planted sweet corn attractive to beetles
- Beetles leave field corn and move into sweet corn (late planted - after June 1)
- Soil type makes a difference - sandy soils have less of a problem

Chemical treatments: (Soil-applied insecticides for larval control)

Organophosphates - worker safety issues, odor issues (stinks), chronic exposure can cause health problems

Terbufos (Counter CR) @ 6 ounces per 1,000 ft. of row

- Level of control = Good
- Interaction with some herbicides, Accent primarily, will cause crop injury
- Worker safety issues
- REI- PHI=Not applicable for soil/seed treatment

Chlorpyrifos (Lorsban 15G) @ 8 ounces per 1,000 ft. of row

- Level of control = Fair to good
- REI- PHI=Not applicable for soil/seed treatment

Phorate (Thimet 20G) @ 6 ounces per 1,000 ft. of row.

- Level of control = Not used, not available
- Worker safety issues
- REI- PHI=Not applicable for soil/seed treatment

Chlorethoxyphos (Fortress 5G) @3.25 ounces per 1,000 ft. Of row in 30 inch -row spacings

- Level of control = Poor
- REI- PHI=Not applicable for soil/seed treatment

Organophosphate + Pyrethroid
Tebupirimphos+cyfluthrin (Aztec 2.1G) @ 6.7 ounces per 1,000 ft. of row.
- Level of control = Good
- Its two modes of action gives less chance of resistance, broader spectrum of control
- REI-   PHI=Not applicable for soil/seed treatment

Pyrethroid - broader spectrum of control
Teflutrhin (Force 3G) @ 4 ounces per 1,000 ft. of row
- Level of control = Good to excellent
- Costs a little more but safer for applicators to use than OPs
- REI- PHI=Not applicable for soil/seed treatment

Bifenthrin (Capture 2E) 0.30 fl oz per 1,000 ft of row.
- Level of control = Fair
- REI- PHI= 1d

Carbamate
Carbofuran (Furadan 4F) @ 2 pints per acre – broadcast post- (at cultivation)
- Level of control = not much used
- Rescue option but little used otherwise
- REI-   PHI=Not applicable for soil/seed treatment

Other pest management aids:
- Change in tillage or sanitation; not effective for this pest.
- Monitoring systems - whole plant-beetle counts in continuous corn, scout soybean fields to base treatment decisions in following season.
- Crop rotation is biggest control option

Pipeline pest management tools:
- Potentially BT corn hybrids not a near term solution; may need multiple events to help control rootworm larvae.
- Other neonicotinoids also being developed for seed treatments

"To do" List
Research needs
- CRW research extended diapause of Eastern variant of Western corn rootworm
- CRW expand insecticide efficacy trails on sweet corn

Education needs
- CRW educate growers on diapause information when available
- CRW educate growers on results of insecticide efficacy trails on sweet corn

(Chemical treatments for adult beetles)
- In the eastern Corn Belt, in areas of continuous corn; growers are encouraged to rotate crops.
- In the western Corn Belt treatment for adult beetles primarily occurs to prevent economic egg laying.
- In sweet corn adults often are killed as a result of control measures used for aphids or other insects.

Organophosphate
- Many OP insecticides have offensive odors

Chlorpyrifos (Lorsban 4E) @ 1 to 2 pints per acre
- Level of control = Fair --minor use
- REI-24hrs   PHI= 35d

Methyl Parathion (Penncap-M) @ 1 to 2 pints per acre
- Level of control= Fair to Good –minor use
- REI-48hrs   PHI= 3d

Carbamates
Carbaryl (Sevin XLR) @ 2 to 4 pints per acre,
Carbaryl (Sevin 80WSP) @ 1.25 to 2.5 pounds per acre

- Level of control= Fair to Good
- REI-12hrs   PHI= 2d
- Used by smaller fresh market growers due to broad spectrum

Pyrethroids

Permethrin (Ambush 2EC)@ 6.4 to 12.8 ounces per acre
Permethrin (Pounce 3.2EC)@ 4 to 8 ounces per acre

- Level of control= Good
- REI-12hrs   PHI= 1d

Esfenvalerate (Asana XL) 0.66 EC @ 5.8 to 9.6 ounces per acre

- Level of control= Not used much, not very effective
- REI-12hrs   PHI= 1d

Bifenthrin (Capture)

- Control= Excellent
- Used most along with Warrior and Mustang, spectrum picks up European corn borer and corn ear worm
- REI-24hrs   PHI= 1d

Lambda-cyhalothrin (Warrior 1E) @ 1.92 to 3.2 fluid ounces per acre

- Level of control= excellent
- Used most along with Warrior and Mustang, spectrum picks up European corn borer and Corn ear worm
- REI- 24hrs   PHI= 1d

Zeta-cypermethrin (Mustang)

- Level of control = good
- Used most along with Warrior and Mustang, spectrum picks up European corn borer and Corn ear worm
- REI-12hrs PHI 3d

Cyfluthrin (Baythroid)

- Level of control = fair to good
- REI-12hrs PHI=Not applicable for soil/seed treatment

Pipeline pest management tools: None listed

Other pest management aids:

- No other practical aids exist

"To do" List

Research needs

-CRW adults- research overwintering model and summer survivorship
-CRW adults- research development of forecast model similar to flea beetle

4 Corn Earworm: [Helicoverpa zea] a.k.a. cotton bollworm, a.k.a. tomato fruitworm.

Biology and Life Cycle

- Adults females oviposit on foliage, either on leaves early in the season or on fresh silks later in the season. Eggs typically hatch 5-7 days after being deposited.
- Corn earworms are migratory in nature and infestations are borne upon winds from southern US.
- Larvae cause damage to the corn by feeding deep inside the whorls, causing holes that measure 1-2 inches across, or by feeding on kernel tissue of ears.
- An estimated 50% of fields are infested annually by 1-3 or more larvae/plant (as high as 90% some years). Quality (larvae contamination) issue

Distribution and Importance:

- Larvae are responsible for considerable ear damage. One larva can render an ear unmarketable.
- Proper timing of insecticide application is critical as there are no control options once larvae enter the ear and are protected by the husk.
- Treatments are most effective during the early silk stage and prior to larvae entering the ear.

- Does not overwinter in this area, migrates from South and flies back in the fall
- Wind patterns used for monitoring
- Small overwintering population (south of I-80)

Chemical treatments:

Organophosphates

Chlropyrifos (Lorsban 4E) @ 1Qt/acre

- Level of control=not much used, not efficacious, PHI too long
- REI-24hrs PHI= 35d

Methyl Parathion (Penncap-M) @ 1 to 2 pints per acre

- Level of control = not much used, not efficacious
- REI-48hrs PHI=3d

Biologicals

Bacillus thuringiensis (several trade names) See individual labels for rates.

- Level of control = poor, not acceptable
- Used by organic growers because no other tools available - used numerous times
- REI-4hrs PHI= 0d

Reduced-Risk

Spinosad (Tracer)

- Level of Control= fair on larvae only, doesn't control adults
- Very expensive
- REI-4hrs PHI-3d

Carbamates

Carbofuran (Furadan 4F) @ 0.25 to 0.5 pints per acre

- Level of control=poor, very little use
- Expensive
- Dangerous to birds
- REI-48hrs PHI= 7d

Methomyl (Lannate LV)

- Level of control= Fair
- REI- 48hrs PHI- 0-3d

Pyrethroids

Permethrin (Ambush 2EC) @ 6.4 to 12.8 ounces per acre
Permethrin (Pounce 3.2EC) @ 4 to 8 ounces per acre

- Level of control = fair to good
- REI-12hrs PHI= 1d

Esfenvalerate (Asana XL) 0.66 EC @ 5.8 to 9.6 ounces per acre

- Level of control = poor to fair, not used
- REI-12hrs PHI= 1d

Lambda-cyhalothrin (Warrior) @ 2.56 to 3.84 fluid ounces per acre

- Level of control=excellent
- REI-24hrs PHI= 1d
- Max rate is lower for hand harvested fresh market growers

Bifenthrin (Capture 2EC) 2.1-6.4 fl oz per acre, actual use rate is around 2.5 fl oz/A

- Level of control= excellent in larvae and adult control
- REI-24hrs PHI= 1d
- Max rate is lower for hand harvested fresh market growers

Zeta-cypermethrin (Mustang)

- Level of control = good
- Used most along with Warrior and Mustang, spectrum picks up European corn borer and CRW
- REI- 12hrs PHI 3d

Cyfluthrin (Baythroid)

- Level of control = fair to good
- REI-12hrs PHI=2d

Pipeline pest management tools*:*

- FO570, formulation of Mustang
- XDE225, new formulation of Warrior from Dow Agrosciences

Other pest management aids:

- Process out damaged kernels - removal in processing by color sorters, and huskers spin off earworms for **processed** sweet corn only

"To do" List

Regulatory needs

- Corn ear worm need to keep pyrethroids labeled

Research needs

- Corn ear worm research biological system, is it overwintering, do pheromone traps work, etc.

Education needs

- Corn ear worm educate fresh market growers on monitoring for earworm
- Corn ear worm fresh market growers - how to spray correctly
- Corn ear worm improve ways of coordinating trapping networks and getting info out to growers, particularly fresh market growers

5. European corn borer [*Ostrinia nubilalis* (Hubner)]

Biology and Life Cycle:

- Corn borers overwinter as larvae in corn stalks and pupate in the spring. Moths emerge from these pupae in May and June, the adults mate and females place eggs on the underside of corn leaves and on other suitable plant species. A second generation occurs in late July-August. In the northern Corn Belt only one generation may occur (univoltine populations).
- The moths prefer the tallest corn for oviposition, and when larvae hatch, they feed on leaf tissue. These larvae mature and pupate, with a second emergence of moths, usually occurring in late July and August.
- Second-generation European corn borer moths prefer late maturing corn for oviposition. The newly hatched second generation larvae feed lightly on leaves, but soon bore into leaf midribs, stalks and ear shanks.
- Ear drop is a problem and stalk tunneling can predispose plant to stalk rots. Economic thresholds for second generation corn borer are difficult to determine because of the long time period of egg laying an the relatively short persistence of foliar insecticides.

Pest Distribution and Importance:

- An estimated 90% of fields are infested annually by 1-3 or more larvae/plant. Quality issue - larvae contamination issue
- Late-planted corn will typically have greater infestations of corn borer and may be treated with more insecticide.
- Problem every year, everywhere
- May be up to three generations or univoltine

Chemical treatments:

Organophosphates

- Most OPs have offensive odor

Chlorpyrifos (Lorsban 15G) @ 5 to 6.5 pounds per acre

- Level of control = very little used
- Worker safety is always a concern
- REI-24hrs PHI= 35d

Chlropyrifos (Lorsban 4E) @ 1Qt/acre

- Level of control= little used

- Expensive
- Worker safety is always a concern
- REI-24hrs PHI= 35d - PHI is too long

Methyl Parathion (Penncap-M) @ 1 to 2 pints per acre
- Level of control = very little used
- Worker safety is a concern
- Not used as much in food industry due to label loss on other crops (pea and bean)
- Not effective on corn ear worm so not used for European corn borer- controlling both pests at same time
- Kills bees
- REI-48hrs PHI= 3d

Biologicals

Bacillus thuringiensis (several trade names) See individual labels for rates.
- Level of control = poor, not acceptable for most growers
- REI-4hrs PHI= 0d
- Some formulations are used by organic growers

Reduced-Risk

Spinosad (Tracer)
- Level of Control= good on larvae
- Expensive
- REI-4hrs PHI-3d

Carbamates

Carbofuran (Furadan 4F) @ 0.25 to 0.5 pints per acre
- Level of control=fair to good - very minor use due to worker safety and cost
- Not rain fast
- Other products work better
- REI- 48hrs PHI=7d

Pyrethroids
- Essential pesticide for control of European corn borer

Permethrin (Ambush 2EC) @ 6.4 to 12.8 ounces per acre
Permethrin (Pounce 1.5G) @ 6.7 to 13.3 ounces per acre - some use
Permethrin (Pounce 3.2EC) @ 4 to 8 ounces per acre
- Level of control = Exellent
- REI-12hrs PHI= 1d

Esfenvalerate (Asana XL) 0.66 EC @ 5.8 to 9.6 ounces per acre
- Level of control = Poor
- REI-12hrs PHI= 1d

Lambda-cyhalothrin (Warrior) @ 2.56 to 3.84 fluid ounces per acre
- Level of control= Excellent
- REI-24hrs PHI= 1d

Bifenthrin (Capture 2EC) 2.1-6.4 fl oz per acre
- Level of control= Excellent
- REI-24hrs PHI= 1d

Zeta-cypermethrin (Mustang)
- Level of control = good
- Used most along with Warrior and Mustang, spectrum picks up European corn borer and CRW
- REI- 12hrs PHI 3d

Cyfluthrin (Baythroid)
- Level of control = fair to good
- REI-12hrs PHI 2d

Pipeline pest management tools*:*

- FO570, formulation of Mustang
- XDE225, new formulation of Warrior from Dow Agrosciences

Other pest management aids:

- Black Light traps for monitoring

"To do" List

Regulatory needs

- European corn borer Keep pyrethroids labeled or find replacements

Education needs

- European corn borer Educate consumers on benefits of GMO crops, biodiversity, etc

6. Southwestern Corn Borer (*Diatraea grandiosella*)

Biology and Life Cycle:

- Its life history and seasonal occurrence are similar to European corn borer. The second generation egg laying usually coincides with silking stage corn. Eggs are laid on both the upper and lower leaf surfaces.
- Heavy second generation infestations can develop even in areas where first generation activity was light.
- In addition to the types of damage caused by European corn borer, second generation Southwestern corn borer larvae increases harvest losses through plant lodging caused by girdling of the stalk 1 to 2 inches above the soil.
- While the biology of Southwestern corn borer is similar to that of European corn borer, peak moth flights occur after those of European corn borer, causing extended periods of corn borer larval activity.
- Weather-related planting delays can cause serious exposure to harvest losses by late-season Southwestern corn borer.

Pest Distribution and Importance:

- Southwestern corn borer usually causes only light damage to early planted corn
- In late corn plantings, first generation larvae can tunnel deep enough to kill the growing point and cause "dead heart"
- Southwestern corn borer is not controlled by DIMBOA based plant resistance which protects small plants from European corn borer feeding
- Treatment for second generation Southwestern corn borer is generally applied when 20 to 25% of the plants are infested with eggs. Often a second application 7 to 10 days after the first is needed if significant egg laying occurs after the first application.
- In BT corn, the same hybrids that have good European corn borer resistance are also resistant to Southwestern corn borer
- When considering chemical control of second generation Southwestern corn borer, consider presence of spider mites in making product selection.
- In the eastern and southern portion of the Corn Belt; parts of Illinois, Indiana, Kansas, Kentucky, and Missouri, there is a complex of European corn borer and southwestern corn borer (Southwestern corn borer) attacking field corn. In these areas, economic losses attributed to Southwestern corn borer is more frequent.

Chemical Controls

Carbamates

Carbofuran (Furadan 4F)

- Level of Control= fair
- REI- 48hrs PHI- 7d

Pyrethroids

Permethrin (Ambush 2E)

(Pounce 3.2E)
- Level of control= Good
- REI-12hrs PHI= 1d

Esfenvalerate (Asana XL)
- Level of Control= Good
- REI-12hrs   PHI= 1d

Bifenthrin (Capture 2EC)
- Level of Control= Good
- REI-24hrs   PHI= 1d

Biologicals

Bacillus thuringiensis (several trade names) See individual labels for rates.
- Level of control = Fair
- REI-4hrs   PHI= 0d

Spinosad (Tracer)
- Level of Control= Good
- REI-4hrs PHI- 3d

Other pest management aids:
- Early planting tends to enable a plant to tolerate damage but does not result in reduced infestation levels
- Avoid late-planted corn; extremely late planted corn may be heavily infested with Southwestern corn borer, and yield losses due to tunneling may be extensive
- Where soil erosion is not a concern, deep, clean plowing of corn stubble to a depth of 5 or more inches will bury larvae and pupae and prevent a high percentage of moth emergence the next spring
- Overwinter survival of Southwestern corn borer is highest where corn stubble is left undisturbed. No-till producers need to be aware of the increased risk. Fall tillage to break up root stubble and expose borers to natural enemies and winter environment can decrease borer survival.

"To Do" List

None listed

7. Black cutworm [*Agrotis ipsilon* Hufnagel], Other cutworm species include: bristly, bronzed, claybacked, dingy, glassy, redbacked, sandhill, spotted, and variegated cutworms.

Biology and Life Cycle:
- A number of cutworm species cause stand losses to young corn in the first month of growth.
- Black cutworms do not overwinter in the north central states. Southerly winds carry moths north from overwintering areas along the Gulf of Mexico, and mated females lay their eggs in fields.
- The moths prefer weedy areas and plant residue to lay eggs.
- Once eggs hatch, larvae will feed on available vegetation. Fields subject to cutworm infestation often have preplant infestations of weeds or heavy surface debris.
- Other cutworm species do overwinter in the Midwest, survival varies with winter weather.

Pest Distribution and Importance:
- Young cutworm larvae (1st-3rd instars) are very small and feed primarily on corn leaves. This injury is not considered economic.
- Larger larvae (4th and later instars) cut the plants off below, at, or just above the soil surface. If the plant is cut below the growing point the plant will not survive.
- Large numbers of black cutworms can drastically reduce the plant stand in given fields.
- In northern regions, tillage or burn down herbicides applied at least two weeks before planting greatly reduces damage by this pest.
- Sporadic pest with catastrophic results when it occurs, occurs more frequently in the southern portion of the region, and should be considered a pest of significant importance.

- Scouting is recommended and thresholds have been developed. Post-emergence rescue treatments are justified when 3% or more of plants are cut and larvae are still present.
- After the V6 stage corn is tolerant.
- Minor pest

Chemical treatments:
Organophosphate

- Not much used due to poor efficacy

Chlorpyrifos (Lorsban 15G) @ 5 to 6.5 pounds per acre
Chlorpyrifos (Lorsban 4E) @ 1 to 2 pts per acre

- Level of control = poor
- REI-24hrs PHI= 35d

Methyl-Parathion (Penncap-M)

- Level of control= poor
- REI-48hrs PHI-3d

Chlorethoxyphos (Fortress 5G) @3.25 ounces per 1,000 ft. Of row in 30 inch -row spacings

- Level of control = poor
- REI-48-72hrs PHI= NA

Pyrethroids

- Insecticides of choice due to broad spectrum

Permethrin (Ambush 2EC) @ 6.4 to 12.8 ounces per acre
Permethrin (Pounce 1.5G) @ 8 ounces per 1000 feet of row
Permethrin (Pounce 3.2EC) @ 4 to 8 ounces per acre

- Level of control = Good
- REI-12hrs PHI= 1d

Esfenvalerate (Asana XL) 0.66 EC @ 5.8 to 9.6 ounces per acre,

- Level of control = Good
- REI-12hrs PHI= 1d

Lambda-cyhalothrin (Warrior) @ 1.92 to 3.2 fluid ounces

- Level of control = Good
- REI-24hrs PHI= 1d

Bifenthrin (Capture)

- Control= Good
- REI-24hrs PHI= 1d

Tefluthrin (Force ST)

- Level of control= Good
- REI-0hrs PHI=Not applicable for soil/seed treatment

Biological
Bacillus thuringiensis (many)

- Level of control = poor
- REI-4hrs PHI= 0d

Pipeline pest management tools:

- Transgenic Bt corn hybrids

Other pest management aids:

- Tillage applied at least two weeks before planting greatly reduces damage by black cutworms.
- Improved Bt hybrids, if accepted by consumers, may provide good control

"To do" List
None listed

8. Stalk borer [Papaipema nebris]
Biology and Life Cycle:

- Stalk borers are a native insect that damages corn by tunneling into plants and typically destroying the growing points. Damage is typically confined to field areas that are adjacent to borders of perennial grasses and broadleaf weeds, including road ditches, terrace backslopes, and grassed waterways.
- Perennial grasses like quackgrass and wirestem muhly and large broadleaf weeds, especially hemp (Cannabis sativa) and giant ragweed (Ambrosia trifida) are favored oviposition sites in the fall, and if these weeds are disseminated throughout the field, general damage can occur.
- Typically, stalk borer damage is limited to border rows, and treatments can be targeted to those border areas.

Pest Distribution and Importance:

- This pest has a moderate level of importance; but local outbreaks can have a significant impact on yields.
- Control weeds and there won't be a significant problem
- Minor pest and rarely treated

Chemical treatments:

Organophosphate

Chlorpyrifos (Lorsban 4E) @ 2 to 3 pints per acre

- Level of control = Good
- REI-24hrs PHI= 35d

Pyrethroid

- Insecticide of choice, good efficacy, availability and cost

Permethrin (Ambush 2EC) @ 6.4 to 12.8 ounces per acre
Permethrin (Pounce 1.5G) @ 6.7 to 13.3 ounces per acre
Permethrin (Pounce 3.2EC) @ 4 to 8 ounces per acre

- Level of control = Good
- REI-12hrs PHI= 1d

Bifenthrin (Capture)

- Control= Good
- REI-24hrs PHI= 1d

Esfenvalerate (Asana XL) 0.66 EC @ 5.8 to 9.6 ounces per acre

- Level of control= Good
- REI-12hrs PHI= 1d

Lambda-cyhalothrin (Warrior) @ 2.56 to 3.84 fluid ounces per acre

- Level of control= Good
- REI-24hrs PHI= 1d

Pipeline pest management tools:

- Bt corn hybrids

Other pest management aids:

- Clean tillage in the spring will destroy most overwintering eggs on weed residues in the field
- Burn field edges and grassy borders in the spring reduces overwintering eggs
- Adjusting planting dates has little or no effect on this pest

"To do" List

None listed

9. Corn leaf aphids [*Rhopalosiphum maidis*]

Biology and Life Cycle:

- Corn leaf aphids are colonial sucking insects that can rapidly increase population numbers to cover the emerging tassels and youngest leaves of stage R1 corn plants.
- This pest does not overwinter in most of the Corn Belt. Winged corn leaf aphids are transported to the Midwest by prevailing winds from southern regions.

- Although corn leaf aphid populations approaching 400 individuals per plant are necessary to warrant treatment, such populations do occasionally occur under favorable (dry) weather conditions.
- The primary damage from large populations is physiological, but secretion of honeydew can cause tassels to gum up and can reduce the effective dissemination of pollen.
- Scouting is most critical under drought conditions, and seed corn producers must pay special attention to protect pollen availability from inbred lines.

Pest Distribution and Importance:

- Except under very dry conditions, this pest is of minor importance to corn production in most areas.
- High densities of actively feeding aphids will cause plant wilting and curling and ultimately necrosis of the upper leaves of the corn plant.
- Aphids excrete honeydew, which coats leaves and reproductive structures and may interfere with pollination. Honeydew also enhances other stalk rots and sooty mold. This can be a particular problem for fresh market sweet corn quality, detracting from the appearance of the silks and husks. Storage and transit may also be a factor in the presence of mold, especially when corn is improperly handled (without refrigeration in display or storage) by retailers.
- Certain hybrids of corn favor aphid survival and they may have up to 9 generations/year.
- Where heavy Johnsongrass infestations are controlled, the aphid populations may move to nearby corn.
- Aphids also carry the Maize Dwarf Mosaic (MDMV) virus.

Chemical treatments:

Chlorpyrifos (Lorsban 4E) @ 1 to 2 Pints per Acre

- Level of Control = Good
- REI-24hrs PHI= 35d

Methyl Parathion (Penncap-M) @ 2 to 3 Pints per Acre

- Level of Control = Good
- REI-48hrs PHI-3d

Pyrethroids

Bifenthrin (Capture)

- Control=Excellent, product of choice
- REI-24hrs PHI= 1d

Lambda-cyhalothrin (Warrior) @ 2.56 to 3.84 fluid ounces per acre

- Level of control =good but weaker than Capture
- REI-24hrs PHI= 1d

Mustang

- Doesn't control as well as other pyrethroids
- REI- 12hrs PHI- 3d

Cruiser

- Control unknown

Pipeline pest management tools:

- clothianidin

Other pest management aids: None listed

"To do" List

Research needs

- Corn Leaf Aphid- need to evaluate Cruiser and other seed treatments for aphid control

10. Corn flea beetles [*Chaetocnema pulicaria* Melsheimer]

Biology and Life Cycle:

- Flea beetles have enlarged hind legs which allow them to jump when disturbed.

- Corn flea beetles feed on corn leaf surfaces where they abrade the surface tissue and cause minor loss of leaf photosynthetic material.
- Two generations of flea beetles appear to be important to sweet corn; the overwintering generation that emerges with earliest plantings as soon as spring temperatures begin to warm, and a second generation that appears to peak about mid-June to early July.
- Numbers of flea beetles and incidence of Stewart's wilt decreases between early peak (associated with overwintering generation of beetles) and a second peak (associated with the second generation of flea beetles).
- Size of flea beetle populations late in the season are important in determining the size of the population that enters overwintering and subsequently, may vector *E. stewartii*, the following spring.

Pest Distribution and Importance:

- Flea beetles play a major role in the transmission of Stewart's wilt, a bacterial disease of corn. The incidence of Stewart's wilt is generally tied to winter conditions that favor winter survival of corn flea beetles. The average air temperatures (in degrees F) for December, January and February are averaged and if the average is greater than 32, Stewart's wilt is of special concern. If the 3-month average is below 32, the risk is relatively small due to dead beetles.
- The feeding damage they cause to sweet corn leaves disrupts physiological processes. Damage is most severe when corn is young, <6 inches tall, and when growing conditions stress developing seedlings.
- Scout and apply rescue treatments should corn flea beetle numbers reach the economic threshold.
- Distribution is moving northward, more of a problem now than previously, especially in warm winters. 4 of last 10 winters are among the warmest winters in the last 100 years.
- Threshold is 1 in 100 plants in corn less than 6 inches tall, hybrid dependent

Chemical treatments:

Organophosphates

- Most have low efficacy and very little used

Chlorpyrifos (Lorsban 4E) @ 2 to 3 Pints per Acre

- Level of Control = not used
- REI-24hrs PHI= 35d

Methyl-parathion (Penncap-M) @ 2 to 3 Pints per Acre

- Level of control = not used
- REI-48hrs PHI-3d

Terbufos (Counter 15G) @ 8 ounces per 1,000 ft. of row

Terbufos (Counter CR) @ 6 ounces per 1,000 ft. of row

- Level of control = not used
- REI-48-72hrs PHI= used at planting

Phorate (Thimet 20G) @ 6 Ounces per 1,000 Ft. of Row

- Level of Control = not used
- REI-48-72hrs PHI=Not applicable for soil/seed treatment

Carbamates - low efficacy

Carbofuran (Furadan 4F) @ 2.5 Fl Ounces per 1,000 Ft of Row

- Level of control = not used
- REI- 48hrs PHI- 7d

Carbaryl (Sevin XLR) @ 1 to 2 Quarts per Acre

- Level of control = good
- Not used by processed growers, used by some fresh market growers
- Used by fresh market growers because is isn't an RUP and has broad spectrum
- Good retention on plant surface (XLR formulation)
- REI-12hrs PHI= 2d

Pyrethroids

Permethrin (Ambush 2EC) @ 6.4 to 12.8 Ounces per Acre
(Pounce 3.2EC) @ 4 to 8 Ounces per Acre

- Level of control = good to excellent
- REI-12hrs PHI= 1d

Esfenvalerate (Asana XL) 0.66 Ec @ 5.8 to 9.6 Fl Ounces per Acre

- Level of control = good, little use
- Narrower spectrum
- REI-12hrs PHI= 1d

Lambda-cyhalothrin (Warrior) @ 2.56 to 3.84 Fl Ounces per Acre

- Level of Control = good to excellent
- REI-24hrs PHI= 1d

Bifenthrin (Capture 2EC) 1.6 - 6.4 Fl Ounces per Acre

- Level of Control =excellent
- REI-24hrs PHI= 1d

Zeta-cyfluthrin (Mustang)

- REI- 12hrs PHI- 3d
- Level of Control - Good

Neonicotinoids

- For highly susceptible hybrids these are the preferred method of control in a high risk area - seed treatment

Imidacloprid (Gaucho)

- Level of control = excellent
- seed treatment
- REI-12hrs PHI-7d

Thiamethoxam (Cruiser)

- Level of Control = Excellent control
- Seed treatment
- Works better in drier soils than Gaucho
- Some research shows that Cruiser may increase plant vigor and plants mature earlier

Pipeline pest management tools:

- Neonicotinoids
- Clothianidin (TI-435)

Other pest management aids:

- Hybrids vary in tolerance to Stewart's wilt disease.

"To do" List

Research needs

- Corn flea beetle Need better information from which to predict size of flea beetle populations to determine when to apply seed treatment insecticide or avoid use of moderately susceptible or Corn flea beetle susceptible hybrids.
- Corn flea beetle Need a field friendly test kit to determine if beetles transmitting Stewart's Wilt
- Corn flea beetle Need to continue hybrid sensitivity screening
- Corn flea beetle Need overwintering model updated
- Corn flea beetle Need to establish geographical zone recommendations and differentiate between quality (Fresh market) and yield issues.

11. Sod webworm [*Crambus* sp]

Biology and Life Cycle:

- One generation per year occurs in the Midwest. Webworms that attack corn overwinter as partly grown caterpillars which developed in sod or other grasses the previous summer and fall. Larvae feed on leaves and may also cut the stalk like cutworms. Larvae are active as soon as corn emerges. Threshold levels for control are similar to corn cutworms.

Pest Distribution and Importance:

- This insect is an occasional pest of corn and treatments are rarely required.
- This is a minor pest to corn production, usually in fields of corn planted into grass sod.

Chemical treatments:

Organophosphates:

Chlorpyrifos (Lorsban)

- Control = Good
- REI-24hrs PHI= 35d

Pyrethroids

Permethrin (Pounce 1.5G) @ 6.7 to 13.3 ounces per acre

Permethrin (Pounce 3.2EC) @ 4 to 8 ounces per acre

- Level of control = Good
- REI-12hrs PHI= 1d

Lambda-cyhalothrin (Warrior) @ 2.56 to 3.84 fluid ounces per acre

- Level of control = Good
- REI-24hrs PHI= 1d

Bifenthrin (Capture)

- Control= Good
- REI-24hrs PHI= 1d

Pipeline pest management tools: None listed

Other pest management aids:

- Tillage of grass sod the year before corn production reduces populations since moths do not lay eggs in bare soil.

"To do" List

None listed

12. Hop vine borer (*Hydraecia immanis*)

Biology and Life Cycle:

- Hop vine borers are soil dwelling and bore into the base of young corn plants where they destroy the growing points.
- Localized infestations can be intense and are often associated with weedy fields

Pest Distribution and Importance:

- Very targeted regionally - very similar life cycle to stalk borer - more of a pest in the northern latitudes.
- Considered a minor corn production pest.
- Timing of controls must be exact.

Chemical treatments:

Pyrethroids

Permethrin (Pounce 3.2EC) @ 4 to 8 ounces per acre

- Level of control = Good
- REI-12hrs PHI= 1d

Pipeline pest management tools: None listed

Other pest management aids: None listed

"To do" List

None listed

13. Fall Armyworm *Spodoptera frugiperda* **True Armyworm** [*Pseudaletia unipuncta* Haworth]

Biology and Life Cycle:

- Fall armyworm overwinter and move northward annually from southern states because they cannot overwinter in locations where the ground freezes.
- Larvae range in color from light tan to black. They have a distinct inverted "Y" on the front of their head capsule. Fall Armyworm reach lengths of 1-1½ inches. Adult moths arrive from the gulf-coast states on strong southerly winds, similar to black cutworm.
- True armyworms overwinter in the north and favor grass as an oviposition site. Often, the damage to young corn happens suddenly when the grass supply is consumed or when it is killed with a herbicide treatment.
- No-till fields must be observed closely, and treatments should be based on the presence of small army worm larvae feeding on the grass and the level of damage to corn.

Pest Distribution and Importance:

- Very sporadic, but when it appears, it can be a significant pest - capable of destroying entire fields.
- True Armyworms often move from wheat fields to corn fields as the season progresses.
- Armyworm damage is characterized by ragged feeding and large amounts of frass (fecal pellets) on plants. The most severe damage occurs in sweet corn fields that are no-tilled into grass or alfalfa sod.
- Scouting and spraying of field perimeter is an effective method of control - no-till corn field near rye or other grassy field.
- This pest is considered of low to moderate importance to sweet corn production.
- Minor pest, regional problem on year to year basis, grassy weeds and cover crops - control grassy water ways
- **Fall armyworm**, -harder to kill than true armyworm, a problem later in the season in the north but can be a problem early on for late planted sweet corn in Illinois. Fall armyworm is an aggressive feeder.
- Application timing critical, kill before silking process
- Products of choice are pyrethroids, Pounce, Capture and Mustang. OP usually have poor efficacy

Chemical treatments:

Organophosphate

- Not used for fall armyworm due to poor efficacy

Chlorpyrifos (Lorsban 4E) @ 1 to 2 pts/acre

- Level of control = poor
- REI-24hrs PHI= 35d

Methyl Parathion (Penncap-M) @ 2 to 3 pts/acre

- Level of control = poor
- REI-48hrs PHI-3d

Carbamates

Carbaryl (Sevin)

- Control=good especially in fresh market
- REI-12hrs PHI= 2d

Methomyl (Lannate LV) @ 0.75 to 1.5 pints per acre

- Level of control = Good
- REI-48hrs PHI= 0-3d

Biological

Bacillus thuringiensis (several trade names)

- Level of control = some activity, used by organic growers
- REI-4hrs PHI= 0d

Spinosad (Tracer)

- Control= Good
- REI-4hrs PHI- 3d

Pyrethroids

- Products of choice

Permethrin (Ambush 2EC) @ 6.4 to 12.8 ounces per acre
(Pounce 1.5G) @ 6.7 to 13.3 ounces per acre
(Pounce 3.2EC) @ 4 to 8 ounces per acre – prior to brown silk stage

- Level of control= Good
- REI-12hrs PHI= 1d

Esfenvalerate (Asana XL) 0.66 EC @ 5.8 to 9.6 ounces per acre

- Level of control = Good
- REI-12hrs PHI= 1d

Bifenthrin (Capture)

- Control= Good
- REI-24hrs PHI= 1d

Pipeline pest management tools: None listed
Other pest management aids: None listed
"To do" List
Research needs

- True armyworm monitoring data needed
- True armyworm need research on biology/life cycle for fall armyworm
- Fall armyworm need research on sweet corn planted into wheat stubble

Education needs

- True armyworm educate producers on the need to monitor for this pest

14. Twospotted spider mite [*Tetranychus urticae* Koch] and Banks Grass Mite [*Oligonychus pratensis*]

Biology and Life Cycle:

- Twospotted spider mite has very broad host range, reproducing on grass and broadleaf crops and weeds. Banks grass mite is restricted to grassy crops and weeds. Both species have high reproductive rates, and short life cycle and can produce multiple generations in a growing season.
- Spider mites feed on the underside of lower leaves, moving up the plant as populations develop. They feed by sucking juices from leaf cells, leaving yellow dots where they feed. When abundant they can kill leaves.
- Infestations at the level of the ear often cause economic yield losses. Populations may increase after insecticide applications made for other insects, because broad spectrum insecticides kill predatory insects and mites which help suppress mite population growth. Populations may rebound quickly after miticide application, because except for propargite, miticides are not effective against eggs, and miticides also kill mite natural enemies (predatory mites and insects).

Pest Distribution and Importance:

- Spider mites are controlled during most years by a naturally occurring disease and arthropod natural enemies (predator spider mites and insects). However, when there are prolonged periods of low humidity, the fungus is suppressed, allowing the spider mite population to proliferate. If adverse weather conditions continue, re-treatment may be needed.
- In the eastern Corn Belt region it is not considered a pest of importance on corn. More commonly they are a pest in the western Corn Belt.
- Two spotted spider mites are less susceptible to most pesticides than Banks grass mite.
- Banks grass mite may colonize corn early in the season as small grains or pasture grasses mature. Two spotted spider mites normally colonize corn later in the season (late whorl-reproductive stages)

Chemical controls: spot treatments are recommended if only part of the field is infested; re-infestation and resurgence is possible after treatment due to egg hatch and destruction of beneficial insects and mites.

Organophosphate

Dimethoate (Cygon 400) @ 1 pt. per acre.

- Level of control = Good
- REI-48hrs PHI= 14d

Organosulfite

Propargite (ComiteII) 2.5 qt per acre

- Level of control= Good
- REI=7d PHI -30d

Pyrethroids

Bifenthrin (Capture) 2EC 2.1 to 6.4 fl oz per acre

- Level of control = Good
- REI-24hrs PHI= 1d

Pipeline pest management tools: None listed

Other pest management aids:

- Bt corn hybrids may decrease mite outbreaks by decreasing use of broad spectrum insecticide for corn borers. (Bt sweet corn has not been readily accepted by consumers)

"To do" List

None listed

15. Grasshoppers (predominantly 4 species: **differential** [*Melanoplus differentialis* Thomas], **twostriped** [*Melanoplus bivittatus* Say], **redlegged** [*Melanoplus femurrubrum* DeGeer], **migratory** [*M. Sanguinipas*])

Biology and Life Cycle:

- Grasshoppers are common mid- to late-summer pests of corn. These insects hatch in grassy field edges and other grassy areas where they will feed, and then gradually spread into production fields. The presence of grasshoppers in border areas is not necessarily a cause of alarm.
- Adult grasshoppers are better controlled with some of the pyrethroid and carbamate insecticides.

Pest Distribution and Importance:

- Cultural practice of delayed mowing of ditch banks etc will assist in keeping the grasshoppers out of production fields.
- Grasshoppers are considered of low importance to corn production.
- Greatest yield losses are caused by the loss of leaf area during tassel and silking stages. A 20% loss of leaf area during this time will result in about 7% loss in yield. However, scouting is pertinent, because it is important to only treat when the population reaches economic thresholds.

Chemical treatments:

Organophosphate

Chlorpyrifos (Lorsban 4E)@ 0.5 to 1 pt/acre

- Level of control = Good
- REI-24hrs PHI= 35d

Methyl Parathion (Penncap-M) @ 2 to 3 pints per acre

- Level of control = Good
- REI-48hrs PHI-3d

Dimethoate (Cygon)

- Control = Good
- REI-48hrs PHI= 14d

Carbamates

Carbaryl (Sevin)

- Control = Good
- REI-12hrs   PHI= 2d

Pyrethroids

Esfenvalerate (Asana XL 0.66 EC) @ 5.8 to 9.6 ounces per acre

- Level of control = Good
- REI-12hrs   PHI= 1d

Cyhalothrin (Warrior) 2.56-3.84 fl oz per acre

- REI- 24hrs PHI- 1d

Zeta-Cypermethrin (Mustang) 2.9-4.3 fl oz per acre

- REI- 12hrs PHI- 3d

Bifenthrin (Capture)

- Control= Good
- REI-24hrs PHI= 1d

Pipeline pest management tools: None listed

Other pest management aids:

- Sanitation: Avoid trimming weeds and grass around field border during dry weather to discourage grasshoppers from moving into the corn field.

“To do” List

None listed

16. Western bean cutworm (*Loxagrotis albicosta*)

Biology and Life Cycle:

- Western bean cutworm is a pest that can severely damage ears, resulting in potentially large yield and grain quality problems.
- One generation per year; larvae overwinter in soil. Populations survive overwintering best in well drained soils.
- The adults oviposit on upper surfaces of corn leaves or on dry edible field bean leaves. Corn fields in late whorl stage are the most attractive to females for egg laying.
- New larvae are about ¼ inch in length and are dark brown. These larvae feed on pollen and then move to ears where they feed until dropping to the ground and form a subterranean overwintering chamber.

Pest Distribution and Importance:

- Timing of treatments is critical, because once the larvae reach the ear tips they are then shielded from the insecticide.
- Fields treated with pyrethroid insecticides should be monitored closely for subsequent spider mite infestations.
- Typically a pest in Nebraska, Kansas, Colorado; recently has also been found in NW Iowa and southern MN.

Chemical Controls:

Organophosphates:

Chlorpyrifos (Lorsban 4E)@ 0.5 to 1 pt/acre

- Level of control = Good
- REI-24hrs PHI= 35d

Methyl Parathion (Penncap-M) @ 2 to 3 pints per acre

- Level of control = Good
- REI-48hrs   PHI-3d

Carbamates

Carbaryl (Sevin XLR Plus) 2 qts per acre

- Control = Good
- REI-12hrs   PHI= 2d

Pyrethroids:

Permethrin (Ambush 2EC)@ 6.4 to 12.8 ounces per acre
Permethrin (Pounce 3.2EC)@ 4 to 8 ounces per acre

- Level of control= Good
- REI-12hrs PHI= 1 d

Esfenvalerate (Asana XL) 0.66 EC @ 5.8 to 9.6 ounces per acre

- Level of control= Not used much, not very effective
- REI-12hrs PHI= 1d

Bifenthrin (Capture)

- Control= Excellent
- Used most along with Warrior and Mustang, spectrum picks up European corn borer and Corn ear worm
- REI-24hrs PHI= 1d

Lambda-cyhalothrin (Warrior 1E) @ 1.92 to 3.2 fluid ounces per acre

- Level of control= excellent
- Used along with Mustang, spectrum picks up European corn borer and Corn ear worm
- REI- 24hrs PHI= 1d

Zeta-cypermethrin (Mustang)

- Level of control = good
- Used most along with Warrior, spectrum picks up European corn borer and Corn ear worm
- REI-12hrs PHI- 3d

Other Pest Management Aids:

- Bt foliar sprays not effective against western bean cutworms

Pipeline Pest Management Tools:

- Future Bt corn hybrids may provide some suppression

"To Do" List:
Research

- Need to establish threshold and level of western bean cutworm importance on sweet corn.

17. Japanese Beetle

- Japanese beetles are about 5/8 inch long and overwinter as a larva or grub in the soil.
- The strong-flying adults typically emerge from the soil in July in great numbers and feed heavily upon available foliage. Soaking rains can also cause damage, as it urges successive invasions by the beetles.
- If effective insecticides are not used on affected areas beetles from afar will tend to make their way to the fresh sweet corn.

Chemical treatments:
Organophosphate
Chlorpyrifos (Lorsban 4E)@ 0.5 to 1 pt/acre

- Level of control = Good
- REI-24hrs PHI= 35d

Methyl Parathion (Penncap-M) @ 2 to 3 pints per acre

- Level of control = Good
- REI-48hrs PHI-3d

Dimethoate (Cygon)

- Control = Good
- REI-48hrs PHI= 14d

Carbamates
Carbaryl (Sevin)

- Control = Good
- REI-12hrs PHI= 2d

Pyrethroids

Esfenvalerate (Asana XL 0.66 EC) @ 5.8 to 9.6 ounces per acre
- Level of control = Good
- REI-12hrs PHI= 1d

Cyhalothrin (Warrior) 2.56-3.84 fl oz per acre
- Level of Control = Good
- REI- 24hrs PHI- 1d

Zeta-Cypermethrin (Mustang) 2.9-4.3 fl oz per acre
- Level of Control = Good
- REI-12hrs PHI 3d

Bifenthrin (Capture)
- Control= Good
- REI-12hrs PHI= 1d

Pipeline pest management tools: None listed
Other pest management aids: None listed
"To do" List
None listed

18. Sap beetles
- The sap beetle overwinters as an adult in soil or debris.
- The adult beetle is approximately 1/8 inch long and black with white or yellow spots on the wing covers.
- Adults feed on ripening pollen, chew tassels, and damage kernel tissue allowing diseases to enter the plant.
- Sometimes used as a beneficial insect for European corn borer before July 4, feed in tunnels of European corn borer and kills European corn borer. After July 4 becomes a pest.
- Incidental to control of other pests
- Exposed tip hybrids are more susceptible
- Application window for sap beetle is 10 days to 0 days before harvest

Chemical treatments:
Products used to control corn ear worm and European corn borer also control sap beetle

Organophosphate
Chlorpyrifos (Lorsban 4E)@ 0.5 to 1 pt/acre
- Level of control = not used
- REI-24hrs PHI= 35d

Methyl Parathion (Penncap-M) @ 2 to 3 pints per acre
- Level of control = Good
- REI-48hrs PHI-3d

Carbamates
Carbaryl (Sevin)
- Control = poor to fair
- REI-12hrs PHI= 2d

Pyrethroids
Esfenvalerate (Asana XL 0.66 EC) @ 5.8 to 9.6 ounces per acre
- Level of control = used very little
- REI-12hrs PHI= 1d

Cyhalothrin (Warrior) 2.56-3.84 fl oz per acre
- Level of control = good, some used
- REI- 24hrs PHI- 1d

Zeta-Cypermethrin (Mustang) 2.9-4.3 fl oz per acre
- Just registered in 2002
- Level of control = good

- REI-12hrs   PHI-3d

Bifenthrin (Capture) preferred method of control

- Level of Control = good
- REI-24hrs PHI= 1d

Pipeline pest management tools: None listed

Other pest management aids: None listed

"To do" List

Research needs

- Sap beetles, need research on predictive life cycle model
- Sap beetles, (do producers have information that Universities do not on how to control?)

Insecticides:

Annual insecticide use, rates of application and number of applications is estimated in Table 6. A brief summary of labeled application rates and REI and PHI restrictions are found in Table 7. Also included in Table 7 is more detailed information about insecticides use for specific insects.

Insecticide use varies annually by region and by pest. Fresh market sweet corn produced on commercial farms, may use more insecticide than sweet corn for processed uses. Typically fresh market sweet corn will spray insecticide closer to the date of harvest to insure fewer insects contaminate the corn which is sold on the ear.

Table 6. Insecticide: area applied, rate, and number of applications for 2003

Insecticide	Area Applied (%)	Rate/ Application	# of applications
Chlorpyrifos	1	1.16	1
Permethrin	30	0.11	3
Tefluthrin	30	0.12	3
Terbufos	1	1.24	1
Cyfluthrin	30	0.006	3
Tebupirimphos	1	0.12	1
Imidacloprid	10	10oz/100# seed	1
Lambda cyhalothrin	50	.02	3
Bifenthrin	30	.02	3
Zeta-cypermethrin	50	.025	3

Table 7. Insecticide Rates, MOA, REI, PHI and Target Insects

Trade Name	Common Name	Rate/Acre Low.....High	Unit	REI Hrs	PHI Days	Primary Target
Ambush, Pounce	permethrin	0.1---0.2	lb	12	1	cutworms, flea beetles, european corn borer, corn earworm,
Asana	esfenvalerate	0.03---0.05	lb	12	1	cutworms, flea beetles, corn earworm
Aztec	cyfluthrin +tebupirimphos	see label		48	P	corn rootworm
Baythroid	cyfluthrin	0.0125---0.044	lb	12	2	cutworms, european corn borer, corn earworm, fall armyworm
Capture	bifenthrin	0.033---0.10	lb	18** 24***	1	flea beetles, european corn borer, corn earworm, fall armyworm
Counter G	terbufos	0---1	lb	48	P	corn rootworm
Diazinon	diazinon	1-2	pt	24	7	flea beetle, aphid, corn earworm, sap beetle, grasshopper, rootworm beetle
Force 1.5G and 3G	tefluthrin	3---5	oz/ 1000 ft	0	P	corn rootworm
Furadan	carbofuran	0---2.5	fl/oz	48	P / 7	flea beetles, European corn borer, corn earworm
Gaucho	imidacloprid	8---16	floz/100 #seed			flea beetles
Lannate	methomyl	0.23---0.45	lb	48	0-3	corn earworm, fall armyworm
Lorsban	chlorpyrifos	1---1.5	lb	24	35	cutworms, flea beetle,
Lorsban G	chlorpyrifos	0---1	lb	12	P	corn rootworms
Mustang 1.5EW	zeta-cypermethrin	2.4-4.3	oz	12	3	corn rootworm adults, corn earworm, corn borer
Penncap M	methyl parathion	1-2	pt	48	3	black cutworm, armyworm, flea beetle, aphid, corn earworm, European corn borer, rootworm beetles, sap beetles
Sevin	carbaryl	1---2	lb	12	2	sap and picnic beetles,corn earworm, european corn borer, japanese beetle, flea beetles
SpinTor	spinosad	0.023---0.094	lb	4	3	fall armyworm, corn earworm, european corn borer,
Thimet G	phorate	0---1	lb	48-72	P	corn rootworm
Warrior	lambda -cyhalothrin	0.02---0.03	lb	24	1	cutworms, flea beetles, european corn borer, corn earworm, fall armyworm

P=apply at or before planting or as early in season side-dress according to label
Fresh * Processed

Diseases

For sweet corn, the most frequently cited diseases and pathogens are: seedling diseases and blights (Pythium, Fusarium, and Penicillium), leaf blights (Northern Corn Leaf Blight, anthracnose leaf blight, and gray leaf spot) Stewart's wilt and blight, viruses (Maize dwarf mosaic) rust and smut.

Fusarium species of fungi, in particular, increase when crop residues are present. These fungi commonly cause root rot and also invade corn stalks, causing stalk rots. Many leaf blights are spread through plant residue. Corn seeds are treated to avoid infection by spores in the soil and on the seed. Essentially all corn seed is treated with a broad-spectrum protectant fungicide that adds very little additional cost to production. Some foliar spraying may be necessary.

Table 8. Estimates[4] of Crop Loss and Acres Infested by Diseases

Common Name	Scientific Name	Avg. Acres Infested*	Avg. % Crop Loss**
Common Rust	Puccinia sorghi	10	10
Common Smut	Ustilago maydis	15	7
Maize Dwarf Mosaic Virus	MDMV	1	1
Northern Corn Leaf Blight	Exserohilum turcicum	0	0
Stewart's Wilt and Blight	Erwinia stewartii	1	1
Seedling blight	Collectotricum graminicola		
Gray leaf spot	Cercospora zea-maydis		
Barley Yellow Dwarf Mosaic	BYDM		

* Infested at economic level
** Loss averaged over last 3 to 5 years.

1. Seed Decay and Seedling Blight
Biology and Life Cycle:
- These diseases are generally caused by soil-inhabiting fungi such as *Pythium, Fusarium, Diplodia, Rhizoctonia,* and *Penicillium*.
- These fungi also may be seedborne, except for *Pythium*.
- Seeds may be rotted before germination or the seed may germinate and the seedling infected and blighted (damping-off). This can occur as either pre-emergence damping-off or post-emergence damping-off.

Pest Distribution and Importance:
- Damping-off is favored by cool, wet soils, so it is more common in low-lying or poorly drained areas or in fields planted too early in the spring.
- Penicillium 4-leaf die-back is favored by warm temperatures
- Pythium seedling blight and seed rot is favored by wet soils and cool temperatures
- Seed rot and seedling blight due to Fusarium spp. Is favored by any environmental condition that hampers seedling growth and vigor (usually a combination of cold temperature and wet soils).
- Heavy residue on the soil surface can favor damping-off by suppressing soil temperature and drying.
- Other factors that delay germination and emergence such as herbicide damage, compaction, crusting, or planting too deep, can result in more seedling blight.
- Seed/seedling diseases are controlled by seed treatment only.
- Human exposure to chemical seed treatment materials, once the seed is in the ground, is minimal and would only occur when loading seed into planter and checking planter boxes or moving seed. Seed comes already treated in bag.
- Very little corn replanted due to seedling blight because of treated seed.
- Seed treatment lasts just long enough to get seed germinated.
- In the absence of seed treatments severe losses would be incurred in localized areas.
- Have to establish a good, uniform stand, seed rots detract from this

Chemical controls:

Need to be broad spectrum to control all potential problems - This is CRITICAL

Phenylpyroles

Fludioxonil (Maxim)
- Level of control = good to excellent for Penicillium/Fusarium, fair for Pythium
- Seed comes pre-treated.
- REI- PHI= Does not apply to seed/soil treatment

Phenylthalimides

Captan (Captan)

- Level of control = fair to good
- REI- PHI= Does not apply to seed/soil treatment

Phenylamides

Metalaxyl (Apron)

- Level of control = excellent for Pythium, poor to none for others
- REI- PHI= Does not apply to seed/soil treatment

Mefenoxam (Apron XL)

- Level of control = excellent for Pythium, poor to none for others
- REI- PHI= Does not apply to seed/soil treatment

Pipeline pest management tools: None listed

Other pest management aids:

- Damping-off is generally controlled by seed treatment with a fungicide on almost all seed corn. This is sufficient in most cases, but not under severe conditions.
- Plant corn when the soil temperature is above 50/F and soil moisture is not excessive.
- Seeds should not be planted too deep; about 1 1/2 to 2 inches is best, depending on soil conditions.
- Improved field drainage/ later plantings on warmer soils.

"To Do" List:

Regulatory

- Seed decay and blights; have to keep Captan registered - need its broad spectrum

- Seed decay and blights: Seed treatment chemicals should be a super crop group when they go through registration (IR-4 crop grouping strategy)

2. Root rots

Biology and Life Cycle:

- Root rots of corn are common, and can be caused by a number of fungal pathogens including *Pythium spp., Fusarium graminearum* and other *Fusarium* species
- Root rots occur to some extent in every field.

Pest Distribution and Importance:

- Wet soil conditions predispose plants to root rots because of oxygen deficiency, and the root rot fungi thrive under these conditions.
- Highly compacted or otherwise poorly drained soils are particularly prone to root rots. Many of the stalk rot pathogens enter through the roots and cause a root rot in advance of the stalk rot.
- Root rots are generally not economically significant and are considered of minor importance to corn production. But under wet conditions, root rots cause economic losses.
- No products are sold to control root rots, therefore very little research has been done on them.
- Root rots may be mis-diagnosed as another disease/injury.
- Common in early sweet corn

Chemical controls:

- The seed treatments used for seedling rots and seed decay have some limited effect on root rots.
- No products are specifically available and labeled to control root rots.

Other pest management aids:

- Under good growing conditions losses to root rots are negligible, and control measures are not necessary.

- Improved drainage reduces the risk of root rots when wet conditions occur. Soil drying can be enhanced through a reduction in surface residue or cultivation, but the value of these practices in reducing root rot has not been demonstrated.

"To Do" List:

Research

- Root rots, research the use of raised beds for fresh market sweet corn

Foliage and Aboveground Diseases

3. Eyespot Aureobasidium zeae

Biology and Life Cycle:

- Eyespot is caused by the fungus *Aureobasidium zeae*, previously known as *Kabatiella zeae*. This fungus overwinters in corn residue and in wet conditions produces conidia that are spread by splashing water and wind.
- The disease is much more common when corn follows corn.
- Eyespot may appear early in the season on lower leaves and again near the end of the season on upper leaves.

Pest Distribution and Importance:

- Eyespot is more prevalent in the northern part of the Corn Belt.
- Early maturing hybrids seem to be more susceptible.
- Field corn is seldom treated with foliar fungicides for this disease.

Chemical Controls

Ethylenebisdithiocarbamates

Mancozeb, (Dithane, Mancozeb, etc)

- Level of control = Good
- REI-24hrs PHI=7 d

Triazoles

Propiconazole, (Tilt)

- Level of control= Good
- REI-24hrs PHI=14d

Strobilurins

Azoxystrobin (Quadris)

- Level of control= Good
- REI-4hrs PHI=7d

Substituted Benzenes

Chlorothalonil,(Bravo)

- Level of control = Good
- REI-48hrs PHI=14d
- Only for fresh market, not for processed sweet corn

Pipeline pest management tools: None indicated

Other pest management aids:

- Resistant hybrids are available.
- Crop rotation or reducing surface residue through tillage reduces inoculum.
- In reduced tillage systems, resistance and rotation are very important control measures.
- Fungicides can be used to control leaf diseases in corn, but usually they are economical only in seed corn, popcorn, or sweet corn production. More than one application is necessary when conditions are favorable for disease.

"To Do" List:

None listed

4. Common smut *Ustilago zeae*

Biology and Life Cycle:

- Common smut is caused by the fungus *Ustilago zeae*, previously known as *Ustilago maydis*, which overwinters in corn residue or soil. This fungus produces black teliospores that survive well in soil. These teliospores germinate during the spring and summer, with each teliospore then producing four smaller spores, called sporidia.
- Infection of ears occurs exclusively from colonization of and infection through silks. Each kernel is infected separately via the silk (extended ovary wall) attached to that kernel.
- Pollenation protects kernels from infection by *U. maydis* as a result of an abscission layer of dead cells that forms at the base of the silk. *U. maydis* is unable to grow across the abscission layer and silks become detached from kernels soon after this layer forms which also prevents infection.
- Aggravated by crop injury from hail, cultivators, etc.
- Sporidia are spread by wind and water.
- All above ground plant parts are susceptible, especially the actively growing meristematic tissue.
- Sporidia can infect through unwounded cells, but wounds caused by insects, detasseling, cultivation, hail, or blowing soil are important infection sites as well.

Pest Distribution and Importance:

- Disease is favored by excess nitrogen, excess manure or herbicide injury, and relatively dry, warm weather.
- Factors that cause the timing of pollen production and silk emergence to diverge (e.g. drought stress) increase the incidence of ear smut.
- This disease is of major importance when it occurs.
- Control can be assisted by avoiding mechanical injury and establishing well-balanced soil fertility.
- Number one disease problem for mechanically harvested fresh market corn.
- Yield, quality and case recovery - smut impacts all of these. (For every 5% of smut one case per ton is lost)
- Hybrid specific losses

Chemical controls:

- This disease does not receive chemical treatment.

Pipeline pest management tools: None listed

Other pest management aids:

- Some hybrids are (marginally) less susceptible than others.
- Rotation and tillage will not affect the occurrence of smut, since the teliospores survive well in the soil.
- Avoiding mechanical damage through cultivation can reduce the risk of disease.
- Maintenance of balanced fertility and avoiding herbicide injury also will reduce the risk of disease.
- Avoid stress that affects timing of pollen production and silk emergence.

“To do” List:

Research

- Common smut; research improved ways to screen for reaction to smut
- Common smut; research mechanisms of plant resistance

5. Northern Corn Leaf Blight

Biology and Life Cycle:

- Northern leaf blight is caused by the fungus *Exserohilum turcicum*, previously called *Helminthosporium turcicum*. There are at least seven races of the fungus.
- The fungus overwinters as mycelium and spores in corn residue. Spores are dispersed by wind and splashing water.

Pest Distribution and Importance:

- This has traditionally been the most consistently damaging leaf disease of field corn in the northern Corn Belt, but its severity has decreased due to improvements in resistance. This disease is important to susceptible sweet corn hybrids.
- It occurs throughout the eastern half of the United States, as far west as eastern Nebraska.
- Disease development is favored by extended periods of leaf wetness (rain or dew) and moderate temperatures (64-81/F).
- Fungicides may be economical if hybrids have moderate to susceptible reactions to Northern corn leaf blight.
- Cyclic problem based on weather pattern, crop rotation and hybrid.
- Can be devastating, losses vary by a factor of 5 annually. Disease has a latent period of 10 days.

Chemical Controls:

Multiple modes of Action are essential for managing resistance development. All currently registered products should remain registered for control of this pest.

Ethylenebisdithiocarbamates

Mancozeb, (Dithane, Mancozeb, etc)

- Level of control= fair
- REI-24hrs PHI=7 d

Triazoles

Propiconazole (Tilt)

- Level of control= fair to good
- REI-24hrs PHI=14d

Strobilurins

Azoxystrobin (Quadris)

- Level of control= excellent, product of choice currently
- Potential for resistance
- REI-4hrs PHI=7d

Stratego (propiconazole plus trifloxystrobin)

- Level of control - good to excellent
- Expensive
- Possibly effective strategy for resistance management

Substituted Benzenes

Chlorothalonil (Bravo)

- Level of control= fair
- REI-48hrs PHI=14d
- Not used for process, used for fresh market

Pipeline pest management tools:

- BAS 500 (pyraclostrobin)

Other pest management aids:

- Northern leaf blight can be controlled by two types of resistance, monogenic or polygenic. The monogenic Ht resistance does not confer resistance to all races of the fungus. Hybrids with an Ht gene may become susceptible if new races appear in the area. Polygenic resistance confers resistance to all races, but the resistance is not as absolute as Ht resistance. The level of polygenic resistance varies among hybrids.
- Crop rotation or reducing surface residue through tillage reduces inoculum. In reduced tillage systems, resistance and rotation are very important control measures. Reducing surface residue may not be a practical solution where conservation tillage is a priority.
- Fungicides can be used to control leaf diseases in corn, but usually they are economical only on moderately susceptible hybrids. More than one application is necessary when conditions are favorable for disease.

“To Do” List:

Research

- Northern corn leaf blight needs better prediction of time of initial application of strobilurins may reduce fungicide applications
- Northern corn leaf blight needs resistance management strategies

Regulatory

- Northern corn leaf blight needs to retain propiconazole registration, modes of action other than strobulurins

6. Northern Corn Leaf Spot *Bipolaris zeicola*

Biology and Life Cycle:

- Northern corn leaf spot is caused by the fungus *Bipolaris zeicola*, previously known as *Cochiobolis carbonum*. There are five known races of this fungus with different virulence characteristics and symptoms. Race 0 is nearly avirulent to corn, and race 1 is virulent on only a few genotypes. Races 2 and 3 are the most common races in the Midwest. Race 2 is not specific for corn genotypes, while race 3 is only a problem on certain susceptible lines. A fifth race has been reported recently.
- B. zeicola overwinters as mycelium and spores in corn residue, and the spores are dispersed by wind and splashing water.

Pest Distribution and Importance:

- This disease is favored by high humidity and moderate temperatures.
- This disease rarely occurs in modern hybrids and is not treated with fungicides.

Chemical controls:

Ethylenebisdithiocarbamates

Mancozeb, (Dithane, Mancozeb, etc)

- Level of control = Good (not used)
- REI-24hrs PHI=7 d

Triazoles

Propiconazole, (tilt)

- Level of control= Good (not used)
- REI-24hrs PHI=14d

Strobilurins

Azoxystrobin (Quadris)

- Level of Control= Good (not used)
- REI-4hrs PHI=7d

Substituted Benzenes

Chlorothalonil, (Bravo)

- Level of control= Good (not used)
- REI-48hrs PHI=14d
- Not for processed sweet corn

Pipeline pest management tools: None listed

Other pest management aids:

- Crop rotation or reducing surface residue through tillage reduces inoculum. In reduced tillage systems, resistance and rotation are very important control measures.
- Fungicides can be used to control leaf diseases in corn, but usually they are economical only in seed corn, popcorn, or sweet corn production. More than one application is necessary when conditions are favorable for disease.

"To Do" List:

None listed

7. Anthracnose leaf blight *Colletotrichum graminicola*

Biology and Life Cycle:

- Anthracnose leaf blight is caused by the fungus *Colletotrichum graminicola*. It overwinters as mycelium or sclerotia in corn residue or seed.
- Several weed species also are hosts and may act as inoculum sources.
- Spores are spread primarily by splashing water.

Pest Distribution and Importance:
- Disease development is favored by wet weather with warm temperatures, especially at seedling stages. Anthracnose is much more common where corn follows corn.
- This disease occurred in outbreak proportions in 2000, but was not much of a problem in 2001. Problems are usually localized but can be severe.
- There is a noticeable trend for greater occurrence in recent years due to reduced tillage.

Chemical Controls:

Multiple modes of action are essential for managing resistance development. All currently registered products should remain registered for control of this pest.

Ethylenebisdithiocarbamates

Mancozeb, (Dithane, Mancozeb, etc)
- Level of control = fair to good
- REI-24hrs PHI=7 d

Triazoles

Propiconazole, (Tilt)
- Level of control = fair
- REI-24hrs PHI=14d

Strobilurins

Azoxystrobin (Quadris)
- Level of control = ?
- REI-4hrs PHI=7d

Substituted Benzenes

Chlorothalonil, (Bravo)
- Level of control = Good
- REI-48hrs PHI=14d
- Not for processed sweet corn

Pipeline pest management tools: None listed

Other pest management aids:
- Avoid moderately susceptible and susceptible hybrids.
- Crop rotation or reducing surface residue through tillage reduces inoculum. In reduced tillage systems, resistance and rotation are very important control measures.

"To Do" List:

Research

- Anthracnose, research better understanding of biology, identification and distribution

8. Gray leaf spot *Cercospora zeae-maydis*

Biology and Life Cycle:
- Gray leaf spot is caused by the fungus *Cercospora zeae-maydis*. The fungus survives as mycelium in corn residue, and spores are dispersed by wind and splashing water.

Pest Distribution and Importance:
- This disease is a problem in the eastern United States, and it has grown in importance in the western Corn Belt as far west as central Nebraska.
- Gray leaf spot is much more common in the southern half of the North Central Region.
- It is particularly severe when corn follows corn and in areas of irrigation.
- Sporulation and disease development are favored by warm, humid weather.
- This is a widespread and economically significant problem in corn production.
- Very few hybrids have tolerance.

- By the time symptoms are readily apparent it may be too late for control measures.
- Primarily a problem on late planted sweet corn.
- Problem in Illinois in seed corn production areas
- Bigger problem in late corn, once symptoms are evident it is a problem, incubation period variable depending on growth stage

Chemical Controls:

Multiple modes of action are essential for managing resistance development. All currently registered products should remain registered for control of this pest.

Ethylenebisdithiocarbamates

Mancozeb, (Dithane, Mancozeb, etc)

- Level of control = good
- REI-24hrs PHI=7 d

Triazoles

Propiconazole, (Tilt)

- Level of control = fair to good
- Timing is critical
- REI-24hrs PHI=14d

Strobilurins

Azoxystrobin (Quadris)

- Level of control = good
- REI-4hrs PHI=7d

Substituted Benzenes

Chlorothalonil, (Bravo)

- Level of control = ?
- REI-48hrs PHI=14d
- Not for processed sweet corn

Pipeline pest management tools:

None indicated

Other pest management aids:

- Some hybrids are more tolerant to gray leaf spot, but control is variable and may not be adequate.
- Crop rotation or reducing surface residue through tillage reduces inoculum. In reduced tillage systems, resistance and rotation are very important control measures.

"To Do" List:

Research

- Gray leaf spot, need research to better understand biology and identification

Education

- Gray leaf spot; educate producers to better understand biology and identification

9. Stewart's Disease *Erwinia stewartii*

Biology and Life Cycle:

- This disease, also called Stewart's wilt or bacterial wilt, is caused by the bacterium *Erwinia stewartii*, which overwinters in the gut of the corn flea beetle (*Chaetocnema pulicaria*).
- The occurrence of this disease is strongly linked to the winter survival rate of the corn flea beetle, because the beetle introduces the pathogen into the corn plants as it feeds and carries the bacterium from plant to plant. The beetles survive in high numbers following a mild winter, resulting in high disease levels. If the sum of the mean monthly temperatures for December, January and February is 90/F or more, the beetles will survive and the threat of Stewart's wilt is high.
- The disease is not spread by insects other than the flea beetle.
- Stewart's disease is also seedborne, but seed transmission is very rare.

Pest Distribution and Importance:

- This disease is more common in the southern and eastern parts of the Corn Belt.
- Sweet corn hybrids can be very susceptible.
- The disease systemically infects susceptible hybrids. Therefore, initial infection of seedlings often causes failure of a plant to produce a marketable ear.
- Yield losses are related to the level of host resistance and growth stage at which plants are infected.
- This disease is of increasing importance in recent years. Perhaps because more flea beetles are able to overwinter due to mild winter temperatures.
- Monitoring for flea beetles is important.
- This disease systemically infects susceptible hybrids, thus , initial infection at seedling stages often causes failure of a plant to produce a viable ear.
- Crop losses can be up to 90% (following mild winters).
- Control includes: wilt-resistant hybrids, insecticide use to reduce insect vectoring, and planting between the overwintering and 2nd generation of flea beetles.
- Stewart's wilt can be managed to a great degree with hybrid selection.
- Bigger problem as go south until hit a point in the south where it doesn't become a problem anymore.
- About number 3 in significance of diseases

Chemical Controls:

- Control flea beetles which is the vector
- Cost effective treatments for disease consist of seed treatments - Cruiser and Gaucho for corn flea beetles

Pipeline pest management tools: None listed

Other pest management aids:

- Most cultural practices do not influence Stewart's disease because the pathogen survives in the flea beetle.
- If flea beetle numbers are extremely high, insecticide applications can reduce the beetle population and disease spread.

"To Do" List:

Research

- Stewart's wilt; Better information from which to predict size of flea beetle populations could be useful in determining when to apply seed treatment insecticide or avoid use of moderately susceptible or susceptible hybrids.

- Stewart's wilt; Research issue of proximity to winter wheat for corn flea beetles
- Stewart's wilt; Research resistant hybrids - genetic resistance to Stewart's wilt
- Stewart's wilt; Develop overwintering model updated for flea beetles

10. Stalk Rots

Biology and Life Cycle:

- Stalk rots are caused by several different fungi that infect plants through the roots or through wounds in the stalk. The major stalk rot pathogens are *Gibberella zeae, Fusarium* species, and *Colletotrichum graminicola* (anthracnose), and *Diplodia sp.*

Pest Distribution and Importance:

- The occurrence of stalk rots is strongly affected by stresses on the corn plant during the grain filling stage of development. Any conditions that reduce photosynthesis and the production of sugars can predispose the plant to severe stalk rot. Such stresses include high plant populations, severe leaf diseases or hail damage, drought or soil saturation, lack of sunlight, extended cool weather, low potassium in relation to nitrogen, and insect damage. Insects such as the European corn borer cause stress to the plant as well as providing wounds for entrance of the stalk rot fungi. Many stalk rot infections can be traced back to stalk boring insect wounds.

- Stalk rots are a sporadic and seasonal problem and are generally considered of minor importance in corn production.

Chemical controls: None listed

Pipeline pest management tools:

Other pest management aids:

- In general, losses to stalk rots can be reduced by scouting fields 40 to 60 days after pollination and looking for symptoms or pinching stalks. If more than 10 to 15 percent of stalks are rotted, the field should be scheduled for the earliest possible harvest.
- Severe stalk rot can be avoided by reducing the stresses that predispose plants. This means balanced fertilization, appropriate plant population and adapted hybrids, insect and weed control, avoidance of root and stalk injury, good drainage, proper irrigation (where applicable), and using hybrids that are resistant to foliar diseases.
- Resistance is available for some stalk rots, and some hybrids are tolerant of stalk rots (will not lodge even if rotted).

"To Do" List:

None listed

11. Ear and Kernel Rots

Biology and Life Cycle:

11a. Fusarium Rots

- Fusarium ear and kernel rot is the most common ear disease in the Midwest. It is caused by several fungi in the genus *Fusarium*, but *F. moniliforme* is considered to be the primary species on corn in the Midwest. Fusarium ear rot occurs under a wide range of weather conditions.
- The fungus causes a stalk rot and can colonize any part of the corn plant, overwintering in the corn residue and on dead grassy weeds. *F. moniliforme* also is commonly found in corn seed.
- *Fusarium* spores are spread by wind and splashing rain to the silks, which are most susceptible for the first 5 days after they appear. Infections also occur through wounds made by insects or other types of wounds in the kernels. Insects can create wounds in which *Fusarium*. *F. moniliforme* can infect and grow throughout the corn plant, and some ear infections may be the result of the fungus entering the ear through the shank, but infection usually occurs in a silk.
- Several of the *Fusarium* species causing corn ear rot can produce a harmful mycotoxin, fumonisin, that has been implicated as a cause of human esophogeal cancer and has been associated with neural tube birth defects in a Hispanic population that consumes large quantities of corn based products.

11b. Gibberella ear rot

This ear rot is common throughout the Midwest. It is caused by the fungus *Gibberella zeae* which is the sexual reproductive stage of *Fusarium graminearum*. This fungus also causes a stalk rot, and overwinters in corn residue. The spores are spread by splashing rain and wind infecting ears through the silks. Silks are most susceptible 2 to 6 days after emergence. The disease is favored by warm, wet weather after silking. This may be the most consistently important mycotoxigenic fungus in the northern Corn Belt, producing vomitoxin, zearalenone, and other toxins.

11c. Diplodia ear rot

Diplodia ear rot is caused by the fungus *Diplodia maydis* (Stenocarpella maydis), which also causes Diplodia stalk rot. This disease is not typically as common as Fusarium or Gibberella ear rots, but it can be destructive when it occurs. The fungus overwinters as mycelium, spores, and pycnidia on corn residue or seed. The spores are spread primarily by splashing rain. The infection process for this disease is poorly understood, but infections first appear at the base of the ear. Corn borer damage in the shank can provide an entry wound for the pathogen. Diplodia rot is favored by cool, wet weather during kernel fill. Rainfall during August, September, and October is correlated with Diplodia ear rot incidence. *D. maydis* is not known to produce harmful mycotoxins. *Diplodia maydis* usually does its damage in the field, but it can be a problem in storage if grain moisture is 20 percent or above. The incidence of Diplodia has increased in the past ten years along with increased minimum tillage.

Pest Distribution and Importance:

- Control of the various ear and kernels rots can be achieved by similar practices. Prevention of their occurrence is difficult because of their dependence on weather and the limited affects of cultural practices.
- These diseases have a high importance to corn production as the toxins produced by molds can be a serious health issue for humans.
- Concern over these diseases could rapidly escalate if FDA sets levels for mycotoxins at unachievable levels.
- Sources of resistance are available in unadapted germ plasm.
- 11 b and c are both more serious problems in sweet corn than 11a.
- All have the same problem with minimum tillage; it causes increased problems in sweet corn - increased levels of inoculum. Problem for all three.
- Serious problem when it appears; which is 4-5 days before harvest.

Chemical controls:

Pipeline pest management tools:

Other pest management aids:

- Plant more tolerant hybrids. Tolerance to the ear rots varies among hybrids, although complete resistance is not available.
- Crop rotation can reduce the occurrence of some ear rots, such as Diplodia. Others may not be affected much because of the movement of spores from neighboring fields.
- Control of insect and wildlife feeding may reduce ear rots to some extent.

"To Do" List:

Research

- Ear & Kernel rot; develop hybrids with more resistance.
- Ear & Kernel rot; research use of Quadris for diplodia control
- Ear & Kernel rot; develop predictive model
- Ear & Kernel rot; research effect of hydro-cooling on disease in storage for fresh market

Regulatory

- Ear & Kernel rot; Evaluate registration of Quadris for diplodia label

12. Common leaf rust: [Puccinia sorghi]

Biology and life cycle:

- The fungus does not overwinter in the Midwest because the final spore stage at the end of a growing season (teliospores) does not infect corn. Urediniospores spread north each season as corn is planted. Thus, rust if of little consequence to early planted sweet corn (or field corn)
- Each uredinum produces about 5,000 urediniospores, so low levels of infection (2-5% severity) at early growth stages (3- to 4- leaf stages) creates an abundance of inoculum that can cause chemical control to be difficult.
- Juvenile leaves of corn plants (i.e. the first four or five leaves on a plant) have different morphology than adult plant leaves, and juvenile leaves are more susceptible to rust regardless of the genetic background of the plants.
- Rust is most severe on late-planted sweet corn because initial inoculum is abundant when plants are at juvenile stages and weather is conducive (cool night, heavy dews) to secondary spread as plants progress from the 5 leaf stage to harvest.
- This disease is aggravated by: cool temps (65-75 F), light rains, heavy dews, and high humidity.
- It is spread when the urediniospores are windblown from previously infected leaves.

Distribution and Importance:

- Losses range from 0-50% (depending on environment and resistance)

- Control includes: resistant hybrids and foliar fungicides (RPD: no. 965)[5]
- Problem on corn planted after June 1
- More of a problem south of Central Wisconsin

Chemical Controls:

Multiple modes of action are essential for managing resistance development. All currently registered products should remain registered for control of this pest.

Triazoles

Propiconazole, (Tilt)

- Level of control = fair to good, better on NLB than rust
- Expensive
- Timing of application is critical
- REI-24hrs PHI=14d

Substituted Benzenes

Chlorothalonil, (Bravo)

- Level of control = poor to fair
- REI-48hrs PHI=14d
- Not for processed sweet corn

Maneb

- Level of control =good
- REI PHI

Strobilurins

Resistance management is key to keep this group

Azoxystrobin (Quadris)

- Preferred method of control
- Level of control =good to excellent
- REI- 4hrs PHI- 7d

(Stratego, Flint, F-500)

- Level of control = excellent

Pipeline pest management tools:

Other pest management aids:

- From the mid-1980s to 1999, rust was controlled in processing sweet corn grown in the Midwest primarily by the use of a single, dominant resistance gene, Rpl-D. Virulence against this resistance was widespread in the US for the first time in 1999. Other single gene resistances are being developed and partial (polygenic) resistance is being improved, but the prolonged usefulness of other Rp genes is questionable.

"To Do" List:

Research

- Leaf Rust; Timing of initial applications of strobilurins need to be examined more closely. Because these compounds are more efficacious than triazoles or other fungicides, they may be applied later and still effectively control rust-thus allowing for a better assessment of whether or not chemical control is actually needed. Strobilurin-resistant fungi are likely to occur- so resistance management strategies should be developed immediately.
- Leaf Rust; Continue hybrid screening (RP1D)

Regulatory

- Leaf Rust; Maintain EBDC - maneb and mancozeb for resistance management
- Need to retain propiconazole registration, modes of action other than strobulurins

13. Maize Dwarf Mosaic Virus:

Biology and Life Cycle:

- This disease is spread by insect vectors (aphids). Several strains of MDMV (or related sugar cane mosaic virus) occur. Effectiveness of host resistance may be affected by strain.

- MDMV-A overwinters in Johnsongrass and is most frequent in areas and fields where Johnsongrass occurs
- MDM usually occurs in sweet corn with the arrival of aphid vectors in June or July.
- Early infections may expose sweet corn to root and stalk rots and cause premature death. Symptoms can appear in the field within 30 days after seedling emerge.

Distribution and Importance:

- Control includes: resistant hybrids and control of rhizome Johnsongrass or other overwintering weed hosts.
- Yield losses are affected substantially by growth stage at which plants are infected. Infection of seedling causes the greatest losses.
- Minor - last three weeks of season, can reduce yield, corn planted after June 15 is at risk
- Stunts plants
- Fresh market - this is biggest problem in the Ohio River Valley (Johnsongrass a problem because it is the overwintering host) Have to take out aphids when Johnsongrass is killed.
- ½ of the fresh market corn is exposed to MDMV.

Chemical Controls:

Pipeline pest management tools:

Other pest management aids:

"To Do" List:

Research

- MDMV: Evaluate effectiveness of seed treatment insecticides on control of MDMV
- MDMV: Clearly understand relationship of strain to host resistance.
- MDMV: Screen for Genetic resistance to MDMV

14. Barley Yellow Dwarf Virus (late season)

Biology and life Cycle

- Virus vectored by several species of aphids (*Rhadophalus padi, R. maidis*, etc.) Strains of the virus are differentiated by vectors.
- Late planted sweet corn seems to be infected most frequently. Symptoms appear late in the summer as chlorosis or purpling of leaf margins resembling K or P deficiency.

Distribution and Importance

- Occurs sproadically throughout the upper Midwest.
- Can cause reduction in yield. Lower case recovery - significant problem
- More common on late season hybrids - after June 15
- Increasing in importance

Chemical controls: None listed

Research

- BYDV; research hybrid trials in high pressure spots
- BYDV; research seed treatment insecticides, for aphid control (Gaucho, Cruiser, etc)

Table 9. Fungicides, Brand Names, REI and PHIs, and Treatment Estimations

Trade Name	Common Name	REI Hrs	PHI Days	Target Disease	Percent Acres Treated "2003"
Apron	metalaxyl	48	NA	soil borne diseases	99
Bravo	chlorothalonil	48	14		1
Captan 30-DD, Captan 400	captan	96	NA	seed rot, seedling blights, seedborne diseases	20
Gaucho Insecticide	imidacloprid			stewart's wilt	1-5
Maxim 4FS	fludioxonil	48	NA	seedling blights	80
Mancozeb Dithane	Mancozeb	24	7		0
Quadris	azoxystrobin	4	7	Leaf rust and N. Corn leaf blight	10
Tilt	propiconazole	24	14	leaf blights, rust	20

14. Nematodes

Biology and Life Cycle:

- Nematodes that attack corn are microscopic roundworms, approximately 3/10 to 3/64 inch long.
- There are many species of nematodes that feed on corn. Dagger and spiral nematodes may be the most common and widespread nematodes

Pest Distribution and Importance:

- Every cornfield contains nematodes actively feeding on plants. The presence of nematodes depends on the soil type and its properties, other soil microorganisms, cropping history, climatic factors such as temperature and rainfall, tillage practices, and the use of pesticides.
- Corn nematodes can feed without causing appreciable yield loss if nematode numbers are low and/or the environmental conditions are such that the corn crop is not stressed.
- Needle nematode probably is the most damaging, but is not widespread. The most important species that is a parasite on corn is the lesion nematode *P. penetrans*.

Nematicides:

Many effective nematicides have been removed from the market and very few new nematicides are being developed, but a few compounds (including some soil insecticides) are still labeled for control of plant-parasitic nematodes on field corn.

Pipeline pest management tools:

None indicated

Other pest management aids:

- Management options for control of nematodes on corn are limited.
- Cultural control strategies such as crop rotation, delayed planting, and alternative tillage have little effect on corn nematode densities and nematode-resistant corn hybrids are lacking.

"To Do" List:

None listed

Table 10. Weed Control Ratings from Various Weed Management Practices

Blank=poor control or unknown (Product/practice not used) F=fair control G=good control E=excellent control	1. Barnyardgrass 2. Wild proso millet 3. Crabgrass			4. Fall panicum 5. Foxtails, 6. Woolly cupgrass 7. Field sandbur				1. Shattercane 2. Johnsongrass 3. Quackgrass 4. Nutsedge				1. Morningglory 2. Bur cucumber 3. Cocklebur 4. Jimsonweed				1. Common ragweed 2. Giant ragweed 3. Smartweed 4. Wild sunflower 5. Velvetleaf					1. Pigweed/waterhemp 2. Lambsquarter 3. Kochia 4. Nightshade				**Winter Annuals** 1. Bromegrass 2. Henbit/chickweed 3. Horseweed 4. Mustards			
PPI & PRE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Atrazine 90DF	F	F	F		F		F			F	F	G	F	G	E	E	G	E	G	G	E	G	G	G	F	G	G	E
Princep-simazine	G		F	F	G							G		G	G	E	G	G	G	G	E	G	F	G	G	G	G	E
Micro-Tech-alachlor	E	F	E	E	E	F	F	P+-	N	N	F	P	P	N	P+	N	N	F+	P+	P	G	F	P	G				
Dual II Mag-metolachlor	E	F	E	E	E	F	F	P+	N	N	F	P	P	N	P+	N	N	F+	P+	P	G	F	P	G				
Frontier-Outlook dimethenamid	G	F	E	E	E	F	F	P+	N	N	F	P	P	N	P+	N	N	F+	P+	P	G	F	P	G				
Prowl-pendimethalin	E	F	G	G	E	G	G	P	P	P	P	N	N	P	P	P	P	F	P	F+	G	G	F	P				
Eradicane/Sutan-EPTC&Butylate	E	G	E	E	E	G	G	G	G	F	G	N	N	P	P	P	P	F	P	G	G	F	F	F+				
POST																												
2,4-D amine												E		E	F	G	G	F	G	G	E	E	F	F			G	E
Aim Carfentrazone		F										G		P	F	P	P	P	P	E	G	G	G	G				F
Callisto-mesotrione		G												G		G	G	G	G	G	E	G	P+	G				G
Accent-nicosulfuron	E	G	P	G	G	G	G	E	E	G		F	F	P	G	P	P	G	P	N	G	P+	G	P				
Permit-halosulfuron											G	F	F	E	F	E	G	F	E	E	E		F					
Atrazine+Oil	F	F	F		F	F	F			F	F	G	F	E	E	E	G	E	E	G	E	E	G	E				
Roundup-glyphosate (Burndown)	E	E	E	E	E	E	E	G	G	G	F	G	E	E	E	G	G	G	E	G	E	E	E	E	E	E	G	E
Celebrity	G	G		G	G	G	G	E	G	G		G	G	G	G	G	G	E	G	G	E	G	G	G				
Basagran-bentazon														G	G	G	G	G	G	F	F	F	F	F				
Laddok												G		G	G	G	G	G	G	E	G	G	G	G				
Adjust Plant/harvest date																												
Tillage								F	F	F	F														G	G	G	G
Paraquat																									F	G		F

References

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5.6.All RPDs reference Report on Plant Diseases. Bulletins issued by number by the University of Illinois Department of Crop Sciences, Urbana, Illinois, 61801.
7.University of Minnesota Vegetable Production and Pest Management Website
http://www.vegedge.umn.edu/vegpest/swtcorn/corn.htm
8.University of Illinois Sweet Corn Disease Reports (See Pataky above)
http://www.sweetcorn.uiuc.edu/report2000/

Vegetable Insect Management. Foster & Flood

Appendix A Herbicide Modes of Action

ALS-inhibitors and amino acid derivatives (HRAC code B)
inhibits amino acid synthesis (ALS acetolactate synthetase), which is first step in amino acid synthesis (proteins not replenished & growth ceases): flumetsulam, halosulfuron, imazapyr, imazethapyr, nicosulfuron, primisulfuron, rimsulfuron

PSII inhibitors (non-mobile) (HRAC code C3)
prevent electron transfer, excess electrons develop and results in formation of singlet oxygen O2- and HO- which destroys lipid membranes: bentazon, bromoxynil

PSII inhibitors (mobile) (HRAC code C1)
blocks electron flow in PSII (Hill) reaction, preventing electron transfer, excess electrons develop and breakdown cells: atrazine, cyanazine, metribuzin, simazine

Root-mitosis- inhibitors (HRAC code K1)
disrupt mitosis by inhibiting tubulin-spindle apparatus formation during cell splitting: pendimethalin

Shoot inhibitors (HRAC code K3)
inhibition of lipid synthesis but other processes also active: acetochlor, alachlor, dimethenamid, EPTC, flufenacet, metolachlor

Growth-hormone- regulator (HRAC code O)
stimulates irregular cell growth and may loosen connections between cell walls, other processes also active: 2,4-D, clopyralid, dicamba

Pigment synthesis inhibitor (HRAC code F2)
affect enzymes of carotenoid synthesis which prevents chlorophyll formation (unknown target enzyme): impinging light develops free radicals for further destruction: isoxaflutole, mesotrione

Protein synthesis inhibitors (HRAC code G)
inhibits amino acid synthesis EPSP synthase (amino acids are not replaced): glufosinate, glyphosate

ACCase inhibitors (HRAC code A)
inhibits acetyl CoA carboxylase with lipid synthesis in meristem primarily affected, lipids not replenished: sethoxydim, quizalofop, fluazifop, clethodim

PPO inhibitors (HRAC code E)
inhibition of protoporphyrinogen oxidase (PPO) results in development of free radical and lipid: peroxidation (breakdown of chloroplasts ect)

Appendix B Fungicide Modes of Action

Information abstracted from:
http://www.ndsu.nodak.edu/instruct/gudmesta/lateblight/Modified/PDFdocuments/fungicides.PDF
Not all products listed may be registered for field corn.

Protectants
Dithiocarbamates: ferbam, thiram, ziram:
Interfere with oxygen uptake and inhibition of sulfur containing enzymes
Ethylenebisdithio-carbamates EBDCs: mancozeb (Manzate, Dithane M-45, Penncozeb, Fore), maneb (Dithane M-22), zineb (Zineb)
Breaks down to cyanide, which reacts with thiol compounds in the cell and interferes with sulfhydryl groups
Phenylpyroles: fludioxonil (Maxim), fenpiclonil:
Affects membrane transport
Phenylthalimides: captan (Captan 50WP, Captan 80WP, Captec 4L):
Degrades to thiophosgene which inhibits fungal enzymes
Substituted Benzenes Pentachloronitrobenzene or PCNB (Terraclor, Turfcide, Blocker), Chlorothalonil (Bravo, Daconil, Echo, Evade, Equus)
PCNB induces lysis of mitrochondrial membranes
Chlorothalonil inhibits sulfur-containing enzymes

Curatives
Benzimidazoles: benomyl (benlate), Thiabendazole (Mertect), thiphanate-methyl (Topsin-M)
Inhibition of mitosis by preventing polymerisation of beta-tubulin
Dicarboximides: iprodione (Rovral, Chipco 26019), vinclozolin (Ronilan)
Unknown mode of action
Phenylamides (Acylalanines) metalaxyl (Ridomil, Subdue, Apron) mefenoxam (Ridomil Gold, Subdue Gold, Apron XL) fluoronil (Ultraflourish)
RNA synthesis inhibition

Sterol inhibitors
Triazoles: triadimefon (Bayleton), triadimenol (Baytan), propiconazole (Tilt, Orbit, Break, Banner), myclobutanil (Rally, Nova, Eagle), cyproconazole (Sentinel, Alto), tebuconazole (Folicur, Elite, Raxil), fenbuconazole (Indar, Enalbe, Govern), difenconazole (Dividend), hexaconazole (Anvil), tetraconazole (Emminant), flusilazone, epoxiconazole, flutriafol (Impact)
Inhibition of sterol biosynthesis (demethylation inhibitors DMI)

Strobilurins
Beta-methoxyacrylates: azoxystrobin (ICIA5504, Abound, Quadris, Heritage) trifloxystrobin (Flint), Gem, Pyraclostrobin (BAS500)
Disruption of electron transport in cytochrome bc1 complex

Appendix C Insecticide Modes of Action

Growth Regulators

These compounds are either hormone mimics or enzyme inhibitors. Some (like methoprene), are analogs to insect juvenile hormones. Their presence causes the larvae of target insects to remain in a juvenile state. Unable to molt, the larvae eventually die. Since they act like hormones, they are effective at very low concentrations, and can be applied at very low rates. Since most vertebrates (all mammals) do not have receptors for such hormones, they are unaffected by these compounds. The low effective rate and low mammalian toxicity make them very safe. Aquatic crustaceans and some fish, though, seem to have analogous hormones and are quite sensitive to these compounds.

Benzimidazoles

These pesticides are also enzyme inhibitors. They inhibit enzymes involved in assembly of glucose transport structures in the intestines of target pests (roundworms and flatworms). Not being able to absorb glucose, the worms eventually die. Mammals do not have these enzymes and are thus relatively insensitive to these compounds. (Some, such as fenbendazole, also have anti-fungal activity.)

Avermectins

Avermectins are a group of compounds obtained from a common soil fungus (actinomycete). They act on GABA (gamma-aminobutyric acid) receptor sites. GABA is an inhibitory neurotransmitter and acts to limit the transmission of nerve impulses. The avermectins act to keep open a chloride ion channel that controls the GABA receptor. Thus, when avermectin molecules are present, the neuron continues to fire at a high rate, which paralyzes the muscles involved. The only place in mammals where GABA and GABA receptors are found is in the brain (where it is the major inhibitory neurotransmitter). Since avermectins cannot cross the blood-brain barrier except at levels much higher than normal therapeutic levels, these compounds are relatively non-toxic to mammals. In insects and roundworms, GABA receptors are found distributed throughout their nervous systems, particularly in skeletal or body muscles.

Organophosphates

Organophosphate compounds cause an irreversible modification of acetylcholinesterase. When this enzyme is deactivated, acetylcholine in synapses is not broken down after its use and continues to cause the receiving neuron to fire. This leads to convulsions and paralysis of the muscle cells involved. Since acetylcholine is the main neurotransmitter between nerve cells in all type of mammalian tissues, these compounds are usually quite toxic to mammals as well as to other vertebrates and insects. In some cases, mammals have enzymes that can degrade certain organophosphate compounds (such as malathion), and these particular compounds are not quite as toxic as the others.

Pyrethroids

Pyrethrum, the original pyrethroid, was obtained from flowers of a tropical chrysanthemum species. However, most pyrethroids currently in use are synthetic, though their basic structure is patterned after natural pyrethrins. They act on the axon of the neuron on the transmitting side of a synapse. They either cause a sodium ion channel on that axon to stay open too long or they prevent it from closing. This causes the neuron to either transmit a very weak pulse or to fire repetitively. The muscle cells involved thus do not receive the nerve impulse or they are overexcited. In either case, the muscles are paralyzed. Mammalian sensitivity is much lower than that of insects because of fewer binding sites and because the pyrethroids can be broken down by esterases in mammalian cells.

Imidothiazoles

The imidothiazoles bind to acetylcholine receptors on the receiving side of a synapse. This, of course, causes the receiving neuron to fire just as if acetylcholine had bound to the site. However, the imidothiazole molecule cannot be broken down and inactivated by cholinesterase so the nerve cell continues to fire. This results in spastic paralysis of the muscle cells involved.

Pyrimidines

These have the same mode of action as the imidothiazoles (acetylcholine mimic).

Organochlorines

Work by overstimulating the nervous system causing convulsions and uncontrolled muscle movements. These products are not cholinesterase inhibitors. Lindane is an example of an organochlorine.

Carbamates

These have essentially the same mode of action as organophosphate insecticides. Carbofuran is an example of a carbamate insecticide.

Appendix D Active Ingredient and Mode of Action for List

	Active Ingrediant (ai)	Trade name	Class
Insecticides	*Bacillus thuringiensis*	Dipel, MVP, Javelin	Biological
	Bifenthrin	Brigade, Capture	Pyrethroid
	Carbaryl	Sevin	Carbamate
	Carbofuran	Furadan	Carbamate
	Chlorethoxyfos	Fortress	Organophosphate
	Chlorpyrifos	Lorsban	Organophosphate
	Cyfluthrin(+Tebupirimphos)	Aztec, Baythroid	Pyrethroid + Organophosphate
	Diazinon (+Lindane)	Kernel Guard	Organophosphate + Organochlorine
	Dimethoate	Cygon	Organophosphate
	Esfenvalerate	Asana	Pyrethroid
	Fipronil	Regent	Phenylpyrazole
	Imidacloprid	Gaucho, Gaucho Xtra, Prescribe	Chloronicotinyl
	Lambda-cyhalothrin	Warrior	Pyrethroid
	Lindane (+Diazinon)	Kernel Guard	Organochlorine + Organophosphate
	Methyl Parathion	Penncap-M	Organophosphate
	Methomyl	Lannate	Carbamate
	Permethrin	Ambush, Pounce	Pyrethroid
	Permethrin	Kernel Guard Supreme	Pyrethroid
	Phorate	Thimet	Organophosphate
	Tebupirimphos + Cyfluthrin	Aztec, Baythroid	Organophosphate + Pyrethroid
	Spinosad	Tracer	Biological (Naturalyte)
	Tefluthrin	Force, Force ST, Proshield	Pyrethroid
	Terbufos	Counter	Organophosphate
Fungicides	Azoxystrobin	Quadris	Strobilurin
	Captan	Captan	Phenylthalimide
	Chlorothalonil	Bravo	Substituted Benzene
	Fludioxonil	Maxim	Phenylpyrole
	Mancozeb	Dithane, Mancozeb	Ethylenebisdithiocarbamates
	Metalaxyl	Apron	Phenylamide
	Propiconazole	Tilt	Triazole
			Class fb HRAC Mode of Action
Herbicides	2,4-D	Many on the market	Chlorinated phenoxy O
	Acetochlor	Doubleplay, Harness, Surpass, (in FulTime)	Acetamide K3
	Alachlor	Lasso, Micro-tech	Acetamide K3
	Atrazine	Atrazine, Extrazine, (in Laddok, Marksman)	Triazine C1
	Bentazon	Basagran, (in Laddok)	Other C3
	Bromoxynil	Buctril, Contour, (in Buctril+Atrazine)	Other C3
	Butylate	Sutan Plus	Thiocarbamate N
	Carfentrazone	Aim	Aryl triazolinone E
	Clethodim	Select	Cyclohexanediones A
	Clopyralid	Hornet, Scorpion, Stinger	Picolinic acid O
	Clomazone	Command	Isoxazolidinone F3
	Dicamba	Clarity, (in Celebrity, Distinct, Marksman, NorthStar)	Benzoic acid O
	Diflufenzopyr	Distinct,	Semicarbazone P
	Dimethenamid	Frontier, Outlook	Acetamide K3
	EPTC	Doubleplay, Eradicane	Thiocarbamate N
	Fluazifop	Fusilade	Aryloxyphenoxyproprionates A
	Flumetsulam	Accent Gold, Hornet, Python	Sulfonanilides B
	Flumiclorac	Resource	N-Pheylphthalimide E
	Flufenacet	Axiom	Oxyacetamides K3
	Glufosinate	Liberty	Phospinic acid H
	Glyphosate	Roundup	Glycines G
	Halosulfuron	Permit	Sulfonylurea B
	Imazapyr	Lightning	Imidazolinone B
	Imazethapyr	Contour, Lightning, Resolve	Imidazolinone B
	Isoxaflutole	Balance	Isoxazoles F2
	Mesotrione	Callisto	Triketones F2
	Metolachlor	Dual II Magnum	Acetamide K3
	Metribuzin	Sencor, Lexone	Triazinone C1
	Nicosulfuron	Accent, Accent Gold, Basis Gold	Sulfonylurea B
	Paraquat	Paraquat	Bipyridylium, Dipyridylium D
	Pendimethalin	Pentagon, Prowl	Dinitroaniline K1
	Primisulfuron	Beacon, (in Exceed, NorthStar, Spirit)	Sulfonylurea B
	Prosulfuron	Exceed, Spirit	Sulfonylurea B
	Pyridate	Tough	Phenylpyridazine C3
	Quizalofop	Assure	Aryloxyphenoxyproprionates A
	Rimsulfuron	Basis, Basis Gold	Sulfonylurea B

Sethoxydim	Poast	Cyclohexanediones A
Simazine	Princep	Triazine C1
Thifensulfuron methyl	Basis	Sulfonylurea B

Appendix E Glossary of Terms Used

A.I. Abbreviation for active ingredient: the amount of pesticidal compound in a formulated product.
Adventitious: The secondary root system of corn which forms above the ground level. Also known as brace roots.
Air-assist: An application method which uses channelized air to assist the delivery of spray droplets.
Annuals: Plants which germinate, flower, and produce seed within a one year period.
Anti-drift: Chemicals added to liquid sprays to reduce the number of fine droplets which have a high potential for drift.
Application: The placement of a pesticide in the field by means of a liquid spray or granular form.
Applicator: A farmer or independent agent for hire who applies a pesticide.
At-planting: The time the crop is planted.
Beneficials: Insects which are considered to be generally advantageous to the crop.
Biochemical: A chemical process that occurs within a living organism.
Biodegradation: Breakdown of a pesticide by living organisms.
Biotechnology: The technology which involves insertion of genetic material into one organism from another organism not closely related.
Biotype: Groups of individuals within a species that bear genetic traits that vary in minute, but identifiable ways from the larger population.
Booms: The extensible arms of a mechanical sprayer.
Broadleaf: Dicotyledonous plants that are typically characterized by netted veins and non-linear formed leaves.
Burn-down: Herbicides used to kill vegetation that is present and actively growing at the time of application.
Carryover: A pesticide that when applied to one crop, persists in the soil to negatively affect crops in succeeding plantings.
Chemigation: Pesticide application directly to a crop by injection directly into an irrigation system.
Commodity Profiles: Documents describing the general pest/pesticide situation faced by producers of a crop.
Conidia : An asexual fungal spore.
Cross-resistance: Development of a resistance mechanism to one pesticide that confers resistance to another pesticide.
Diapause: A period of physiological inactivity occurring at one stage in the life cycle of an insect.
Dormancy: A period of quiescence, enforced or voluntary, where active development ceases.
Edaphic: Of or relating to the soil.
Inbreds: Breeding stock intentionally crossed with parent lines to amplify desirable traits.
Meristematic: Tissue in plants from which new growth originates.
Mycelium: Threadlike, vegetative tubes of a fungal body.
Mycotoxins: Toxins developed from fungal organisms.
Oviposit: Deposition of insect eggs directly to a surface or region.
Perennials: Plants which live for three or more years.
Pheromone: Chemical compounds which convey behavioral signals.
PHI: Pre Harvest Interval: The required time between a pesticide application to a commodity and the harvest of that commodity.
Post-emergence: Pesticide applied after the crop has emerged.
Pre-emergence: Pesticides applied before the crop has emerged.
Pupae: Pre-adult insect developmental stage.
REI: Restricted Entry Interval: Required time between an application and worker entry into a treated field.
Restricted Use Pesticide: Pesticides which must only be applied by a licenced applicator.
Rhizomes: Underground rooting structures of perennial plants from which new shoots may emerge.
Silking: Corn stage where the silks are fresh and emerging from the corn ear.
Smartbox: Enclosed pesticide containers attached directly to corn planters, reducing exposure of operators to the pesticide.
Stacked Traits: The inclusion of more than one genetic trait in one plant from organisms not closely related.
Strip till: Tilling a small strip of soil within which the crop row is planted. This permits the greater portion of the field to remain untilled.
Systemic: Having an action or effect transmitted throughout the entire plant.
Systems-based: Involving the use of multiple approaches to solving a single problem.
T-banded: Application of an insecticide in a narrow band directly over the row and down into the seed furrow.
Tassel: The corn stage where the tassels begin to emerge from at the top of the plant.
Teliospore: Rust spore resting stage that germinates at the end of winter.
TMDL: Total Maximum Daily Load: The maximum permissible exposure limit to environmental contaminants.
Tolerant: An organism which tolerates to some degree, but is not totally resistant to, a non-benign agent.
Transgenic: Insertion of genetic material into one organism from another organism not closely related.
Whorl: Funnel shaped leaf formation found at the top of the corn plant and many other grasses.

Appendix F. Worker Exposure Table for Processed Sweet Corn

Processed		Figures are relative to a 100 acre field.				
In-field event	Dates of event	Number of people involved in event	Hours per event X number of events	Total event hours per season	Level of exposure per season*	Percent of total area traversed /season
Planting	April 1-July 1	1	8	8	1 hr - loading enclosed cab	100
Irrigation	April 10-Sept 30	1	2 X 5	10	minimal exposure <1 hr	10-15
Scouting weeds	Ap 15 - July 1	1	1	1	1 hr	40*
Scouting insects & Diseases	May 1-Sept 30 (July 20-Aug 30)**	1	.5 X 3	1.5	1.5 hr*	45*
Cultivation	May 1- Aug 1	1	8-10	8-10	minimal exposure <1 hr	80
Pre-grading 10 days to harvest	July 5-Oc t 5	1	.5 X 5	2.5	2.5 hrs, wearing slicker suits	100
chemical app: weeds (ground)	Mar 20-July 30	1	4 X 1-2 apps (avg 1.3)	4-8	variable to min. exp <1 hr	99.5
chemical app: diseases (aerial)	July 1-Sept 1	1	1 X 0-2 (avg 0.1)	0-2	minimal exp <1 hr	5-10
chemical app: insects (aerial)	Jun 1-Sept 15	1	1 X 0-4 (avg. 2.2)	0-4	minimal exp <1 hr	80
harvest-mechanical	July 15 - Oct 15	2	2 X 16	32	minimal exposure<1 hr	100

* Level of Exposure per Season is determined by worker contact with seed, soil, plants, or pesticide aerosols or residues.

Appendix. G. Worker Exposure Table for Fresh Market Sweet Corn.

Fresh Market		Figures are relative to a 100 acre field.				
In-field event	Event dates	Number of people involved in event	Hours per event X number of events	Total event hours per season	Level of exposure per season*	Percent of total area traversed /season
Planting	April 1-July 1	1	8	8	1 hr - loading enclosed cab	100
Irrigation	April 10-Sept 30	1	2 X 5	10	minimal exposure <1 hr	10-15
Scouting weeds	Ap 15 - July 1	1	1 X 2	2	2 hr	100*
Scouting insects & Diseases	May 1-Sept 30 (July 20-Aug 30)**	1	.5 X 6	3	3 hr*	100*
Cultivation	May 1- Aug 1	1	8-10 X 2	16-20	minimal exposure <1 hr	80
chemical app: weeds (ground)	Mar 20-July 30	1	4 X 1-2 apps (avg 1.3)	4-8	variable to min. exp <1 hr	99.5
chemical app: diseases (aerial)	July 1-Sept 1	1	1 X 2	2	minimal exp <1 hr	50
chemical app: insects (aerial)	Jun 1-Sept 15	1	1 X 5-7 (avg. 6)	5-7	minimal exp <1 hr	100
harvest - hand	July 8-Sept 15	19	80 X 19	1520	1520	50
harvest-mechanical	July 8 - Sept 15	2	2 X 16	32	minimal exposure<1 hr	50

Appendix H. Distribution Maps of Production and Pests of Sweet Corn


Image Not Available


Image Not Available