Soybean Pest Management

Strategic Plan

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I. Executive Summary

The purpose of a Pest Management Strategic Plan (PMSP) is to communicate, from an industry perspective, the role of pesticides and pest management strategies in crop production. To obtain broad-based industry input, PMSPs are developed for a commodity through the use of workshops which bring together producers, crop consultants, commodity groups and pest management specialists from across the production region. Although PMSPs were originally intended for use by the Environmental Protection Agency (EPA), they have also proved valuable to the United States Department of Agriculture (USDA), Land Grant Universities, and pest management stakeholders at all levels.

This PMSP was prepared at a workshop held on the 7th and 8th of November, 2002, in St Louis. Thirty two participants, representing diverse aspects of soybean pest management and production regions, attended the meeting. Though it is not all-inclusive, this document is meant to be generally representative of pest management challenges faced by soybean producers in the North Central Region. In addition to providing input on pests and pest control methodologies, workshop attendees identified research, education and regulatory issues that impact producer profitability and environmental quality. As part of their final task at the meeting attendees prioritized the issues that they thought were the most critical to soybean pest management in the Midwest.

As mentioned, the original intent of this report was to provide the EPA with the pest management perspectives of soybean producers, consultants, and other pest management specialists. As such, it primarily reflects the comments and inputs of those parties who attended the workshop. 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.

The editors and reviewers of this document 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.

Throughout the text of this document an effort has been made to identify regional differences in pests, their treatment, and the research, educational, or regulatory issues producers in those regions would like to see addressed. The “toolbox” approach we have used has focused on crop protection products and crop production tactics that are important for the economic management of key pests of soybean in the 12 north central states. For many pests, there were significant variations throughout the region regarding which pests were considered “risk drivers” for pesticide use or for grower implementation of other “non-pesticide” practices.

I. Diseases

Soybean diseases are a major threat to profitable soybean production in the Midwest and ongoing “non-pesticide” pest suppression research was credited with mitigating economic losses. The continued need for breeding programs for host resistance to diseases and nematodes was a theme that pervaded the discussions of all other control tactics. In addition, the following issues were perceived as important disease issues for soybean production.

- Although there is little use of foliar fungicides for disease control in the North Central region, all participants were aware of the high risk posed by soybean rust; especially if the more virulent specie were to become established in the United States. Producers and consultants expressed concern about the need to rapidly respond to this disease with accurate information on products, timing, price and pre-harvest intervals (PHI).
- Many products being tested for soybean rust were from the triazole family of fungicides. This triggered concern because the long PHIs associated with these fungicides in wheat may also indicate an excessively long PHI for soybean.
- The search and screening for, and deployment of novel resistance genes for management of soybean cyst nematode, sudden death syndrome, Phytophthora root and stem rot, white mold, and soybean rust were a high priority item for producers.
- Nematicides were generally not deemed to be critical tools for the soybean production in the North Central states, but their continued registration in the southern soybean belt was noted.
- Although fungicides were not being used to a significant extent for white mold control, (an economic disease primarily in the states of Wisconsin, Minnesota and Michigan), many participants viewed the fungicide Topsin M as a key tool and expressed the need for more research into application timing and an educational focus on predictive models for disease management.
- Seed treatment fungicides were viewed as essential complements to host resistance/tolerance for management of Phytophthora.

II. Insects

Three soybean insects, bean leaf beetle, soybean aphid, and spider mites, were considered the key drivers of insecticide use in the North Central region while three essential insecticides were identified in the soybean pest management “toolbox”.

- First, **spider mites** tend to be a problem pest somewhere in the North Central states on an annual basis and a key pest across most of the region once every eight to 10 years. The insecticide considered essential for spider mite control is the organophosphate insecticide **dimethoate**. The organophosphate insecticide **chlorpyrifos** is the second choice of producers in years of heavy spider mite outbreaks when inventories of dimethoate are exhausted. These two products were considered absolutely essential for economic control of spider mites.
- Second, for control of **soybean aphid** and **bean leaf beetle** the pyrethroid insecticide, **permethrin**, is an essential product. Permethrin is the choice for producers because of availability, low use rates, and price. **Soybean aphid** is a new threat to soybean production and its equilibrium with the soybean agroecosystem has not been established, but in some areas 30-50% of fields have been sprayed.
- Within some states or areas other insects are treated on an infrequent but recurring basis.
  - Continued carbofuran registration was considered critical to manage economic grasshopper infestations in the western soybean belt.
  - Japanese beetles, an economic problem in much of Michigan, Illinois, Indiana, Ohio, and eastern and central Iowa, are managed with the same suite of insecticides that are effective against bean leaf beetle.
  - Soybean stem borer is becoming problematic in Kansas, western Missouri, southern Nebraska, northern Oklahoma, and South Dakota. This pest was a priority for soybean

research into the most effective control methods.

III. Weeds

Herbicides are the dominate type of pesticides used on soybean. Economic infestations of weeds are ubiquitous throughout the North Central region. Principal risk drivers across the region that dictate the herbicide program used by producers include foxtails, waterhemp, shattercane, kochia, velvetleaf and lambsquarters. State-specific risk drivers include Palmer amaranth in Kansas, common and giant ragweed in Ohio, and eastern black nightshade in North Dakota, and Johnsongrass south of the Missouri River. Producers listed the following issues as prominent concerns.

- Glyphosate is now the dominant herbicide applied to soybean in the North Central region.
  - Concern was expressed that because of the overwhelming popularity of Round Up Ready soybean, (70% to 80% of the soybean acreage), that a lack of competitiveness in the market may be having a deleterious effect on breeding programs for non-GMO varieties, non-GMO seed availability, and the development of new soybean herbicides.
  - There was considerable concern about the potential development of resistance to glyphosate. Some anxiety was expressed that many producers may not be aware of the risks and costs involved with resistant weeds that could result from regular use of glyphosate products if they fail to take precautions.
- Two herbicides that are not applied directly to soybean were deemed critical for effective and economical weed management in soybean; 2,4-D and atrazine.
  - 2,4-D was viewed as an essential tool for early season burndown of winter annuals, perennial weeds, and broadleaf weeds.
  - Atrazine's efficacy in controlling many of the key broadleaf and grass weeds in corn greatly mitigates weed pressure when fields are rotated to soybean and complements resistance management programs.
- Winter annual weeds and perennial weeds are viewed as becoming more problematic in soybean due to increased no-till practices and the trend away from residual herbicides or the use of lower rates of residual herbicides in corn the preceding year. Producers indicated that research into efficacious management of winter annuals was needed.

II. Soybean Pest Management: Priority Issues for Research, Regulatory and Education

1. All Pests

A. Education

- University researchers, non-governmental organizations, consultants and producers are encouraged to work together closely with on-farm research and demonstrations. Producers recommended that a coalition between land grants, consultants, suppliers, dealers and registrants be developed to promote effective resistance management and pest management systems.

2. Diseases and Nematodes

A. Soybean Cyst Nematode Research and Education:

- Producers indicated that development of alternative sources of resistance should be pursued, especially Chinese germplasm.
- Resistant varieties are expected to lose their resistance so there is a need to keep currently registered products for control. However, in the North Central region, nematicides are not generally viewed as an essential pest management tool for SCN.
- In the southern soybean belt, there is a strong need to keep nematicides registered due to the wider diversity of nematode populations.
- There is a need to continue support for, and refinement of screening methods to determine SCN resistance in soybean varieties.
- There is the perception that up to 20% of 'resistant varieties' are really susceptible - researchers should seek to establish methods by which farmers may know if a "resistant" variety is really resistant.
- There is a need for new, quicker methods of identifying diversity in nematode populations to preempt future problems. The new "race"scheme is viewed positively but producers and seedsmen need information on its proper use and interpretation for making SCN management decisions.
- Need to transfer research information to producers effectively, such as improving producer awareness of problems, different susceptibility of varieties, etc, as farmers currently depend on seed companies for this information.

B. Sclerotinia Research:

- Researchers should develop a predictive model to alert producers when to control (with Topsin M) sclerotinia. This is especially needed with irrigated soybeans.
- *Coniothyrium minitans* is an example of a promising biological control agent that is a potential alternative for control of *S. sclerotiorum*. Further research on this agent would be helpful.
- Researchers need to investigate and develop more tools for control of resistance, i.e. how plant structure (large leaf vs. narrow leaf) affects severity.
- Some current research is investigating mapping one or more genes that confer physiological resistance to *S. sclerotiorum*. Application of a biotech approach to control of sclerotinia would be very helpful.
- Research is needed to investigate the efficacy of new dry bean and sunflower fungicides to see if they can be used on soybeans (other diseases such as downy mildew).

C. Sudden Death Syndrome Research:

- Researchers should evaluate soybean varieties for resistance to SDS.
- Researcher should find ways to develop reliable assays to identify resistance to SDS.
- Researchers are encouraged to incorporate SDS resistance genes in soybean genome.

D. White Mold Research:

- Accelerate research on resistant varieties and determine how plant architecture is related to resistance or disease severity.
- Researchers are encouraged to develop predictive models to time white mold treatments (Topsin-M) more effectively.
- Researchers need to evaluate the efficacy of fungicides now being used on dry beans and sunflowers to see if they can be used on soybeans (other diseases such as downy mildew).
- Producers indicated that research on the impact of irrigation on white mold is important.
- *Coniothyrium minitans* is an example of a promising biological control agent that is a potential alternative for control of *S. sclerotiorum*. Further research on this agent would be helpful. This is an area for biotech approaches. Some current research is investigating mapping one or more genes that confer physiologic resistance to *S. sclerotiorum*.

E. Phytophthora Root Rot Research:

- Researchers should continue to explore new products, especially seed treatments for Phytophthora. Seed treatments (metalaxyl and mefenoxam) are utilized in regions where *P. sojae* is an annual problem.
- IR-4 should investigate new seed treatments for control of water molds.

F. Soybean Rust Regulatory and Education:

- It is important to educate farmers on early identification of soybean rust. The fungus is airborne, and has a life cycle of 4-9 days in South America, and there are four different strains. Two biotypes can cause 20-40% losses and two may cause 40-80% losses.
- Researchers and regulatory agencies are encouraged to label existing compounds for rust control.

3. Insects

A. Bean Leaf Beetle Research and Regulatory:

- Increasing the REI for pyrethroids could be a hardship for producers with workers in the field, irrigation workers, and with researchers in plots. Producers recommend maintaining a 24hr REI.
- Some organophosphates are needed so that insecticide classes can be rotated to forestall resistance, (and also for control of potential outbreaks e.g. spider mites). In addition, supplies of individual products may run out during a pest outbreak, so other products are needed to fill in.
- Researchers should investigate bean leaf beetles as a vector of bean pod mottle virus and determine the dynamics of the spread of bean pod mottle.

B. Soybean Aphid Research:

- Researchers are encouraged to develop solid information about economic thresholds.
- Research is needed to determine appropriate rates of currently available products.
- Research is needed to determine optimal treatment timing and effect on beneficial insects.

C. Western Corn Rootworm Research:

- A better understanding of the biology of the western variant is necessary to provide rationale for control of the Western corn rootworm in corn-soybean rotations.
- More information is requested on whether WCRW adults are carriers of Bean Pod Mottle Virus and other soybean virus diseases.

4. Weeds

A. Winter Annual Weeds Research:

- Research on life cycles is needed so that producers know when and how best to control winter annual weeds, especially henbit, chickweed, marestail (horseweed).
- It is also important for producers to know what insect or disease pests are harbored or hosted by winter annuals.
- Researchers should evaluate winter annual weeds as secondary hosts and attractants for insects and diseases and determine their potential impact on soybean production.

B. Annual Grasses Research and Education:

- Research is needed to determine which grasses will develop tolerance or resistance to glyphosate. Included in these studies should be an effort to determine how the frequency of applications affects resistance or shifts in weed populations. It also may be necessary to seek approval of tank mixes to control these grasses.
- Producers indicated a need for more information on the effect of row widths and the impact of reduced herbicide rates and treatment frequency on weed control.
- More information is also needed on the rates of glyphosate and the interaction between weed size, environmental conditions, and weed control. Product formulation and species diversity may also be considerations in these studies.
- Producers indicated a need to alleviate antagonism in tank mixes that commonly occur with products such as Select, Fusilade, Assure and Fusion.
- Producers also felt that information currently available to researchers, regarding weed shift study results, needs to be communicated to producers.
- Educate producers on rates of glyphosate uses (efficacy of reduced rates) vs weed growth size vs environmental conditions.

C. Perennial Grasses and Sedges Research and Regulatory:

- Research herbicides for control of Johnsongrass in rights-of-way (reduce movement to fields).
- Research is needed to determine which herbicides may control horsetail.
- Research is needed to evaluate application timing - efficacy of spring vs fall application of foliar applied herbicides.
- Researchers are encouraged to find ways to encourage states to control Johnsongrass along rights-of-way.

D. Annual Broadleaf Weeds Research and Regulatory:

- Producers indicated a need to keep atrazine use in corn prior to soybeans for overall weed management in rotations.
- The use of 2,4-D and the maintenance of its registration as a tool for use ahead of soybean planting is deemed very important.
- Producers indicated a need to have information on the role of temperature, humidity, and time of day on various post-applied products.

- Producers indicated a lack of information on how best to control weeds in wheel tracks.
- Improving efficacy while controlling drift (application technology- spray tips and various spray systems, both ground and air) is an increasing concern.
- Producers indicated the need for additional research on spray additives for the most effective control of post-emergence weeds.
- Producers wished to convey to all audiences the need to maintain research on non-GMO plant breeding and herbicides.
- Producers also wished to encourage chemical companies and the EPA to continue researching and registering new chemistries to provide additional tools for problem weed management. It is particularly important to have the herbicides necessary where resistant weeds have developed.
- Research is needed on the effect of additives to tank mixes; which ones work well and how they work.
- Research is also important to determine the weed shifts that are due to lack of tillage and weeds moving into fields from road sides.

E. Perennial Broadleaf Weeds Research:

- Producers indicated a need to develop a system approach for control of perennial broadleaf weeds (to include tillage and conventional pesticide use).
- Producers indicated that research is necessary to develop methods of control for trumpet creeper, Virginia creeper, pokeweed, and mulberry.

F. Herbicide Resistant Weeds Research and Education:

- 2,4-D is a critical tool to have available to control many herbicide resistant weeds. Maintaining this registered use is very important to producers.
- Producers need to use multiple modes of action to control weeds. This is especially true with Round Up Ready soybeans. An educational effort to assist producers in more easily selecting appropriate techniques is needed. This approach should also consider tillage methods.
- Weed resistance problems have been worsened by farm programs and chemical promotional programs. Studies should be conducted to evaluate the negative impact of these programs and determine how they might be mitigated.
- Weed shifts are occurring with the use of some herbicides. Resistant weeds are typically a result of “poor management”, although some seeds from adjacent fields or from blowing pollen may create the problem. Producers would like to have better ways to know which weeds are present and how to appropriately select the herbicide and treat those weeds.

III. Key Soybean Pest Management Tools

Soybean Pest Management Toolbox options	**Relative Importance of tool* Pest(s) controlled Principal reason for rating**
Crop Rotation and other agronomic practices	**Critical:** Long-term soybean cyst nematode management **Important:** White mold management with row spacing and plant architecture
Disease-resistant varieties	**Critical**: Phytophthora root and stem rot (seed treatment fungicides not effective) **Critical:** Sudden Death Syndrome (fungicides not effective) **Critical**: Soybean rust (no fungicides registered, varietal resistance not yet established) **Critical**: Soybean cyst nematode (nematicides not effective or practical) **Critical:** White mold (no control measures other than rotation and row spacing)
Biocontrol agents	**Important**: Soybean aphid (naturally existing biocontrol, diseases and predatory insects are the principal source of aphid management)
Permethrin (and other pyrethroids)	**Critical:** Bean leaf beetle (the most efficacious product)
Organophosphates	**Important:** Bean leaf beetle (shorter PHI than permethrins can be critical depending on time of infestation) **Critical:** Spider Mites (the only effective means of control)
Dimethoate	**Critical:** Spider mites (only effective pest control technique)
Chlorpyrifos	**Important:** Spider mites
Glyphosate	**Critical**: Perennial weeds (no effective substitute)
2,4-D	**Important:** Early season broadleaf weeds (most effective product for broadleaf weed burndown)
Topsin M, triazoles, Strobilurins?	**Important:** White mold **Critical:** Soybean rust
Carbofuran	**Important:** Grasshoppers in western states
Dintroanilines, Acetanilides	**Critical:** Essential for resistance management and non-GMOs
ALS inhibitors and Protoporphyrinogen oxidase inhibitors	**Critical:** Essential for non-GMOs.

IV. Soybean Production in the Midwest

Approximately 70 million acres (28 million hectares) of soybean are grown throughout the twelve-state North Central region with a farm gate value of $11 billion annually. These 12 states in the North Central region produce 40 percent of the world's soybean production. Planting in the soybean belt ranges from mid-March to early July. Double-crop soybean is common in the southern regions and are generally planted from late June to mid-July. Approximately 40 percent of all soybean is consumed by livestock; the remaining is processed for protein and oils, and increasingly as biofuels and whole bean uses by humans. Soybean fields are closely managed and there is a general lack of tolerance for pests by producers. This lack of tolerance is often exacerbated by the level terrain of much of the soybean belt and the ease with which uneven stands or weeds can be seen from the field's edge.

Current cultural practices

- Soybean is typically grown in a rotation with corn and less often with wheat, sorghum, or alfalfa.
- No-till is practiced on about 30 percent of the soybean acreage annually, and some form of conservation tillage practiced on another 20 to 30 percent. Because many producers feel that pest control measures tend to be less effective when soybean is no-till planted, the use of no-till has not appreciably increased for several years.
- About 10 percent of the acreage is cultivated with a row cultivator and an estimated 20 percent is rotary hoed annually.
- Over 95% of soybean acres are treated with at least one herbicide application. Approximately half of all herbicides are applied by the farmer and the other half are applied by commercially licensed dealers and applicators. In general there is a trend for larger farmers to apply a greater proportion of their own herbicides than would producers with small farms.
- A very limited acreage is treated with foliar insecticides or fungicides. Significant fungicide use is generally limited to seed treatment.

Earlier planting

- Cool soils (<50 degrees F @2" depth) during early season planting favors a high incidence of seedling diseases and a concomitant need for effective and low cost seed treatment fungicides. Early planting also tends to shift weed populations toward weeds adapted to grow in cooler temperatures; lambsquarters, mustards, and smartweed species.
- Although planting later in the season is mentioned as a pest control strategy for many of the pests listed in this document, this may not be a practical solution for producers who must take advantage of 'windows of opportunity' to till and plant fields. A delay of a few days typically will result in yield reductions and can, in some years where weather is erratic, result in total crop failure. In order to capitalize on the advantages of early planting, pests must be controlled.

Use of varieties with GMO traits

- The use of varieties with herbicide resistance traits is expected to continue at about the current level of 65 to 90 percent of acres planted in a particular area, ecosystem, or state. Pest populations are expected to shift somewhat in response to changes in herbicide use. Overall, fields planted to varieties with GMO traits, particularly glyphosate tolerance, are expected to have fewer weed problems. An undesirable result of this trend is that GMO use tends to raise the general standard for field cleanliness and appearance, and can result in an attitude among producers that fosters unnecessary pesticide use. On the positive side, maintenance of weed-free fields for a number of years can greatly reduce weed seed populations in the soil, and potentially obviate the need for herbicides in some years.

- There is currently a great deal of controversy over the marketability of grain with GMO traits. While issues regarding the acceptability of grain in both domestic and foreign markets are important to producers, this was not considered as a factor in pest management decision-making or policy for purposes of this PMSP.

Use of conservation tillage

- The Conservation Tillage Information Center (CTIC) estimates that an average of 54% of soybean acres are grown under some type of conservation tillage nationally. Approximately 30% of soybeans are no-tilled each year. These estimates have been relatively steady for the past five years. However, the perception that no-till is declining, especially in the eastern portion of the Corn Belt, is prevalent. Many of the reasons are pest related. Poor stands in no-till are attributed to cool wet soils which result in a greater risk for seed decay, seedling diseases, soil insect injury, and higher weed control costs. Undisturbed soil and the presence of crop residue results in more perennial weeds, the predominance of small seeded grass and broadleaf weeds, and a protective environment for many injurious insects. These trends require an effective array of soil-applied and burn-down herbicides as well as efficacious insecticides with sufficient persistence to adequately control soil-dwelling insects.

Larger farms

- The size of farming operations continues to increase. Large farms operated by a single operator require the use of efficient technologies. Wherever practical, herbicides will continue to replace time-consuming pest management practices such as tillage and row cultivation. Producers will also continue to select technologies and products that allow for single-pass weed control or otherwise reduce the need for multiple trips through the fields. This suggests a continuing preference for pre-mixes and tank-mixes with broad spectrums of control and wide application windows. Larger farms also suggest that more decisions will be turned over to professional agronomists; either those working as dealers and distributors of ag-chem products or to private consultants.

More landlord/tenant operations

- The trend toward farm ownership being passed to those that do not directly operate them is expected to continue. Farmers will compete for available rental farmland and pressure will prevail to maintain high levels of pest control based more on aesthetics and perceptions than on economic thresholds. As a result, the use of pesticides for pest control will become further decoupled from threshold-based treatment levels. The expected outcome is that post emergence herbicide applications will remain in high demand for field cleanups. Keen competition for ‘cash rent’ land is also resulting in producers searching for ways to maintain input costs at low levels. Inexpensive pesticides provide producers with the tools necessary to maintain profitability.

Crop scouting

- Crop scouting is expected to increase slowly but steadily. Passage of the Farm Security and Rural Investment Act of 2002 is expected to provide incentives for farmers and landlords to adopt practices such as crop scouting. Farms that adopt professional crop scouting services are not likely to see immediate reductions in pesticide use, but rather are expected to benefit by having higher yields and lower pesticide expense as pests are managed more effectively in the long run. Many tenant farmers have been reluctant to make such an investment in the past because crop scouting is seen as an outlay of cash without an immediate return.

Pest resistance

- The number and severity of pests that have resistance to some pesticides will grow. This is a result of the repeated use of products that contain similar modes of action and the failure of many producers to observe recommended procedures for avoiding pest resistance. As new instances of pest resistance occur there is a continuing need for a broad array of pesticides with different modes of action, even if many of these chemicals are restricted to an emergency-use-only basis.

Professional pest management and pesticide application services

- More producers are relying on commercial dealers and applicators to select and apply herbicides. Along with this trend comes the knowledge, skill, and latest technological techniques for accurate and effective application of pesticides. The number of crop acres managed by independent crop consultants and farm management services are increasing. The Certified Crop Advisor program, and the potential for their designation as third-party vendors, presents a unique opportunity for a significant increase in the use of professional pest management services.

V. Soybean Diseases: Executive Summaries

A. Soybean Cyst Nematode

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Heterodera glycines, the soybean cyst nematode (SCN), is distributed throughout the soybean production regions of the United States. SCN is responsible by itself for soybean yield losses of hundreds of millions of dollars, and is a factor in the development of diseases that result in significant additional yield losses, including sudden death syndrome (SDS) and brown stem rot (BSR).

Losses due to SCN are controlled through the use of rotation with nonhost crops (such as corn) and SCN-resistant soybean cultivars. Nematicides are not used in the soybean belt for SCN control due to the unfavorable economics associated with their use in soybean production. With appropriate rotation schemes including both nonhost crops and resistant cultivars, yield losses due to SCN can be minimized.

Two factors limit the effectiveness of rotation schemes. First, producers tend to ignore the presence of SCN and grow susceptible cultivars until symptoms (stunting and yellowing) are obvious. Recent research has proven that yield loss can be significant in the absence of obvious symptoms. Ignoring SCN when fields are symptomless can result in up to 30% yield loss. Second, SCN can adapt to resistant cultivars. There are no completely resistant cultivars available, despite some recent claims to the contrary. Consistent planting of the same resistant cultivar in the same field will result in SCN populations that "break resistance" and render the cultivar useless for SCN management. To address these two limitations, IPM educators should continue to emphasize the importance of soil testing for SCN, and the importance of rotating resistant cultivars.

Future research on SCN management must emphasize diversity, both in the soybean and in the nematode. Diverse sources of resistance in soybean must be identified and introgressed into agronomically desirable cultivars to thwart the adaptability of the nematode. Currently in Illinois, for example, 93% of the SCN-resistant cultivars available have the same source of resistance in their pedigrees. Likewise, the diversity within SCN populations that allows them to adapt to resistant cultivars should be emphasized in future research. We need a quick, reliable genetic test that tells us which cultivars a particular population of SCN can attack, so the most effective resistance can be recommended to the grower. The old and new methods of identifying such virulent SCN populations – the race test and the HG Type test, respectively – are both bioassays that take at least 30 days to complete and are very difficult to interpret. Both goals – increasing diversity in soybean cultivars, and identifying diversity in SCN populations – can and should be reached within this decade.

B. Phytophthora Root and Stem Rot

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Phytophthora sojae Kaufmann and Gerdemann causes seed, seedling blight, root and stem rot of soybean when soils are saturated. This disease has been reported from major soybean production regions in the US, but also in Australia, Argentina, Brazil and more recently in the Republic of Korea and People's Republic of China. Losses due to Phytophthora can be substantial depending on the environment and the pathogen population. Historically, there have been individual fields with 100% yield loss during the 1950's through the 1970's. In Ohio, 20% and 40% of the fields in NW Ohio required replanting during 1997 and 2000, respectively; due mainly to *P. sojae*. Annual yield loss estimates (bu/A) from *P. sojae* for the North Central region were estimated to be 40.5, 53.6, 42.2, 26.1, and 40 million bushels for 1996, 1997, 1998, 1999 and 2000, respectively (Wrather et al., 2001). In the southern US, losses due to *P. sojae* were estimated at 0.2% of a total of 1.5 million metric tons of harvested soybeans (Pratt and Wrather, 1998).

Single dominant host resistance genes (*Rps* genes) in soybean have been utilized extensively to manage *P. sojae*. Once incorporated into soybean cultivars and deployed over a wide geographic range, these *Rps* genes have had a "life" of 8 to 15 years. *P. sojae* populations in the US are comprised of many physiologic races with virulence to many of the *Rps* genes that are currently deployed in the US. Partial resistance and seed treatments (metalaxyl and mefenoxam) are also utilized in regions where *P. sojae* is an annual problem. Partial resistance (also termed field resistance, general resistance, rate-reducing resistance and tolerance in the soybean literature) has been shown to be effective against all races of *P. sojae*. For soybeans with high levels of partial resistance, there is little colonization of roots by *P. sojae*.

Current research efforts are focused on identifying new sources of *Rps* genes. In addition, efforts towards identifying molecular markers and cloning known *Rps* genes are in progress. The North Central Soybean Research Program (NCSRP) through the Plant Health Initiative has recently initiated a project which will focus on i) characterizing the populations of *P. sojae*; ii) screen new sources of resistance against isolates from all of the states; iii) identify the levels of *P. sojae* resistance in soybean lines that are sources of resistance for SCN, white mold, brown stem rot; as well as iv) evaluate the effects of cultural practices on minimizing losses to Phytophthora. At the genomic and gene expression level, NSF recently funded a project which will identify genes involved in partial resistance and pathogenicity through the simultaneous use of pathogen/host microarrays and the sequencing of *P. sojae* genome is currently in progress.

Phytophthora is not the only pathogen that is capable of causing soybean stand losses. Research efforts that focus on evaluation of diagnostic kits and development of identification keys will greatly assist producers in these regions. Molecular markers that are versatile for many types of soybean germplasm for all of the known *Rps* genes will greatly enhance cultivar development. In some cases, the current research efforts are greatly underfunded. Additional funding in the current research areas will expedite progress and ensure success towards these goals.

C. Sclerotinia Stem Rot

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Sclerotinia stem rot of soybean, commonly called white mold, is caused by *Sclerotinia sclerotiorum*, a long-lived soilborne fungus. The disease was commonly observed in Michigan, Minnesota and Wisconsin during the 1970's, but was rarely observed in the remainder of the North Central States until the 1990's. Starting in 1992, Sclerotinia stem rot was observed at epidemic levels in most North Central States and remains an annual threat to soybean production throughout the upper North Central region. The sudden increase of Sclerotinia stem rot is likely related to changes in cultural practices that promote dense crop canopies, changes in the genetic base of current soybean cultivars, and an increased incidence of pathogen infested seed.

Yield loss caused by *S. sclerotiorum* is dependent on the percentage of the plant population killed by the pathogen, and how quickly individual plants die in relationship to reproductive development. Field trials indicate that for each 1% increment of plant mortality at the R6-7 growth stages, soybean yield is reduced 0.25 to 0.50 bushels per acre. Yield loss estimates due to Sclerotinia stem rot peaked at 957,000 metric tons in 1997. Yield loss is greatest in years of normal to below normal seasonal temperatures and when yield potential is otherwise high for the crop. Sclerotia of *S. sclerotiorum* are not toxic to humans and livestock.

Sclerotinia stem rot is managed by selecting soybean cultivars with the highest level of resistance and adjusting cultural practices to minimize environmental factors that influence disease development. The severity of Sclerotinia stem rot is greatest in dense soybean canopies created by plantings in narrow row widths, high plant populations, early planting, high soil fertility or other management practices that promote rapid and complete canopy closure. Short-term crop rotation has minimal effect on reducing the severity of Sclerotinia stem rot. However, a preceding crop of small grain, in contrast to corn, may have a moderate impact on reducing the risk of Sclerotinia stem rot. Sclerotinia stem rot is observed less in no-till fields compared to fields receiving some degree of tillage. Thiophanate - methyl (fungicide) will reduce the incidence of Sclerotinia stem rot if applied during flowering and application methods allow the product to penetrate the lower regions of the canopy. An application of 2-6 oz/a of lactofen (herbicide) at the R1 growth stage has a suppressive effect on Sclerotinia stem rot.

Future research will focus primarily on host resistance to *S. sclerotiroum*. Extensive studies have been conducted to identify resistance genes that confer partial or complete resistance. These studies will continue, but will be complemented by studies on mechanisms of resistance, inheritance of resistance, and methods to transfer resistance genes to elite soybean germplasm. Several QTLs have recently been reported in two studies and may map one or more genes that confer physiological resistance to *S. sclerotiorum*. Although temperature and moisture are influential factors, the reaction soybean cultivars to *S. sclerotiorum* are differentially sensitive to photon flux density of photosynethically active radiation. Thus, light is an important environmental variable to regulate when soybean germplasm is evaluated for reaction to *S. sclerotiorum* in controlled environments. *Coniothyrium minitans* is an example of a promising biological control agent that is a potential alternative for control of diseases caused by *S. sclerotiorum*.

D. Sudden Death Syndrome of Soybean

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Soybean sudden death syndrome (SDS) refers to the foliar symptoms caused by a soil borne fungus, *Fusarium solani* f. sp. g*lycines*. It was first documented in the late 1960s in Arkansas and Tennessee and has since become a major concern for the U.S. North Central region. It has also been reported in Argentina, Brazil, Canada, and Thailand.

The fungus infects the root system very early in the growing season, within 2 to 3 weeks after planting, and produces toxins that are translocated from the roots to the leaves. These toxins are thought to be responsible for the foliar symptoms. While SDS brown stem rot and stem canker have similar foliar symptoms, root symptoms of SDS are unique and characterized by browning of vascular tissue in the roots and lower stem with the pith remaining white. Root systems of infected plants are often reduced in size, and under cool moist conditions the taproots are covered by patchy spore masses that are dark blue to blue green in color.

Foliar symptoms are often triggered by a cool, wet period just before or after flowering. Symptoms tend to first appear on lower leaves with yellow or sometimes white blotches appearing between veins. As the disease progresses, the yellow spots will turn necrotic with the mid-vein and major lateral veins remaining green. Eventually the leaflets may fall off leaving the petioles upright.

Yield losses are the result of flower and pod abortion, and reduction of seed size and quality. Yield losses over an entire field may range from 1% to 50% depending upon the growth stage when symptoms appear. However, losses may approach 100% in severely affected areas. Regression analyses from several studies have shown a 6-10% yield loss associated with each 10% increase in disease.

Management of SDS is limited to a few options. Host resistance is the single best control measure. A few varieties have moderate to high levels of resistance and should be selected for fields with a history of SDS. Cool, wet soils at planting tend to promote infection by the fungus. Therefore, early plantings should be avoided. On fields with compaction problems or areas with poor drainage, deep tillage may prove beneficial in reducing SDS. No pesticide or seed treatment has proven effective for control of this disease.

Research on SDS has focused on the development of resistant varieties; identification, location, isolation and characterization of resistance genes; development of greenhouse and field methodologies for varietal evaluation; characterization of the fungal toxins; and cultural control and biocontrol strategies. The United Soybean Board and the North Central Soybean Research Project fund SDS Collaboration Projects that coordinate breeding, pathology and biotechnology approaches to manage this disease. Scientists from Southern Illinois University, University of Illinois, University of Missouri, Purdue University, Iowa State University, University of Arkansas, University of Kentucky, University of Georgia and University of Tennessee are participants.

E. Soybean Rust

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and
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Soybean rust is a major limitation to soybean production. The recent documentation of rust to areas outside of its natural range has led to more interest and concern about the spread of rust. In 1995 it was reported in Hawaii, then in 1998 in Zimbabwe, in 2001 in South Africa, and in 2002 in Brazil and Paraguay. Rust, caused by a more aggressive Asian type *(Phakopsora pachyrhizi*) and a less aggressive type (*Phakopsora meibomiae*), appears to be on the move making it an immediate threat to U.S. soybean production. When rust was confirmed in Hawaii, soybean pathologist from the U.S. convened at a workshop that reviewed the current status of soybean rust in the world and developed an action plan. Most of what has been found so far in terms of movement to new location is *P. pachyrhizi*, the more aggressive of the two species.

One of the first lines of defense would be to employ fungicides. This has been the general practice in Zimbabwe when it was first introduced and now also South Africa, Brazil and Paraguay. In the U.S., states vary as to their registered use of foliar fungicides on soybeans. Most recently APHIS has been involved with emergency action and fungicide labeling for soybean rust in case it is found in the continental U.S. At the present there are no fungicides labeled for use against soybean rust in the continental U.S. The other countries, like Zimbabwe and South Africa, that have recently gone through this process have found **that a number of fungicides (old and newer ones) are effective in controlling soybean rust. The issue with fungicides will be on the timing, the number of sprays and the cost effectiveness.**

Fungicides have been shown to be effective in controlling soybean rust in Zimbabwe, South Africa and Brazil. Efforts to obtain a Federal Crisis Exemption for some candidate fungicides are currently being made at the Department level and the major chemical companies that already have fungicides on the market are making efforts to get labeling changes approved through EPA.

Once an effective fungicide or fungicides are available for use by producers, a recommendation would be made to extension scientists, crop consultants and producers to have sentinel plantings placed strategically in soybean growing areas that would allow for early detection of the disease, which would facilitate producer decisions about protectant applications of fungicides. Since soybean rust manifests primarily on maturing plants, the sentinel plantings should occur about 3 weeks before the commercial crop. This provides an opportunity to observe the first signs of the disease on the sentinels thereby allowing time to effect control of the pathogen in commercial plantings before the disease becomes epidemic. An early protectant application of fungicide will be needed around flowering time when sentinel plants are infected. Subsequent applications may be necessary as the crop matures and the disease begins to intensify.

Dr. Clive Levy, with the Commercial Farmer's Union of Zimbabwe reported that once an infestation of soybean rust is detected, if early enough, effective control was obtained with carefully timed fungicide applications. Detection early in the season with properly timed application of fungicides appears to present the best alternative for controlling soybean rust in the United States. In areas of high rust severity, the first application is at first flowering and then two more applications in 21 day intervals thereafter. In areas with lower severity, the last application is not necessary. In Zimbabwe some farmers found a schedule of first applications 50 days after planting, then at 70 and 90 days after planting. In all cases, but especially in the first applications, it is most effective to apply the fungicides in such a manner that the lower canopy receives treatment.

Currently there are no fungicides registered for soybean rust control in the United States. It is important that more than one fungicide be available in the event they are needed so that resistance development is minimized.

Yield losses for the most part have been taken only on experimental plots. They have been demonstrated to vary greatly with some loss estimates as high as 80%. Soybean producers on several continents have stated that yield losses in their fields were as high as 50%. In the U.S., losses are most likely going to be greatest when the fungus enters the crop early in its development as opposed to late pod-setting stage. Rust can build up very quickly, so even if rust infects the crop during pod fill there potentially still could be significant losses. Other conditions that may be conducive for rust would include high humidity, especially long periods where dew is formed. A crop that is grown in more arid conditions may not get as much rust, although if lush growth and canopy closure occurs early, the microclimate in the canopy may be beneficial to rust. The disease has the capacity to extend to all locations where soybeans are grown with potential losses being greatest in higher production areas where moisture is adequate. The real question will be how the rust fungus exist through the seasons and whether it will have to be reintroduced from somewhere each season and if the conditions for that reintroduction will be conducive for maximum spread or not.

The most fruitful long-term management may well be the use of resistance. Although the development of resistant soybean cultivars for mainstream use in the U.S. may be years away. There has been a recent push from USDA/ARS and USB to evaluate U.S. commercial cultivars, known sources of resistance reported from the literature and other researchers in locations where rust occurs every year. Through this project, international collaborators have been established in Thailand, China, Zimbabwe, South Africa, Paraguay, and Brazil, who are willing to conduct field trials. In addition, U.S. soybean cultivars are being tested at the USDA-ARS BSL-3P Biological Containment facilities at Fort Detrick. The FDWSRU currently is the only location that maintains different soybean rust isolates that will aid in rust resistance screening. In addition to characterizing specific resistance, partial resistance or slow-rusting types, an evaluation of tolerance will be conducted (relatively less loss in yield, but rust susceptible). A combination of both partial resistance and tolerance may have to be developed in breeding lines to reduce the impact of rust. Other long-term solutions also may include incorporating resistance from wild perennial Glycine species and from other sources using genetic engineering.

VI. Soybean Diseases

1. Soybean Cyst Nematode *Heterodera glycines*

Distribution and Importance:

- Currently it is estimated that about 10% of fields have economic levels of soybean cyst nematode (SCN) resulting in $1.2 billion worth of losses nationwide.
- SCN is a factor in the development of diseases that result in significant additional yield losses, including sudden death syndrome (SDS) and brown stem rot (BSR).
- This disease is distributed throughout the soybean production regions of the US. In the Midwest OH, MI (esp Saginaw Valley) it is present but does not usually present visual symptoms.
- This disease would affect grower's management decisions more if they were educated with regards to the impact of this pest.
- In North Dakota and NW Minnesota this disease is not addressed as a problem but is being studied and surveyed by local universities. In Nebraska it is primarily found along the Missouri River.

Non-Chemical controls:

- Losses due to SCN are controlled through the use of rotation with nonhost crops (such as corn) and SCN-resistant soybean cultivars. With appropriate rotation schemes, including both nonhost crops and resistant cultivars, yield losses due to SCN can be minimized.
- Two factors limit the effectiveness of rotation schemes.
    - First, producers tend to ignore the presence of SCN and grow susceptible cultivars until symptoms (stunting and yellowing) are obvious. Recent research has proven that yield loss can be significant in the absence of obvious symptoms. Ignoring SCN when fields are symptomless can result in up to 30% yield loss.
    - Second, SCN can adapt to resistant cultivars. There are no completely resistant cultivars available, despite some recent claims to the contrary. Consistently planting the same resistant cultivar in the same field will result in SCN populations that "break resistance" and render the cultivar useless for SCN management.
- Within the central United States, fewer multiple-resistant cultivars are available as latitude increases.

Chemical controls:

- Nematicides are not used in the Soybean Belt for SCN control due to the perception, and some reality, that economic returns are insufficient for use.
- Low levels of efficacy make available pesticides insufficiently cost effective (Temik and Mocap).
- The interaction of nematicides with some herbicides and the negative effect on yield has lessened use.

"To Do" List

- **Research**: Producers indicated that development of alternative sources of resistance should be pursued, esp Chinese germplasm.
- **Regulatory**: Resistant varieties are expected to lose their resistance so there is a need to keep currently registered products for control. However, in the North Central region,

nematicides are not generally viewed as an essential pest management tool for SCN.

- **Regulatory**: In the southern soybean belt, there is a strong need to keep nematicides registered due to the wider diversity of nematode populations.
- **Research**: There is a need to continue support for, and refinement of screening methods to determine SCN resistance in soybean varieties.
- **Research**: There is the perception that up to 20% of 'resistant varieties' are really susceptible - researchers should seek to establish methods by which farmers may know if a "resistant" variety is really resistant.
- **Research**: There is a need for new, quicker methods of identifying diversity in nematode populations to preempt future problems. The new "race"scheme is viewed positively but producers and seedsmen need information on its proper use and interpretation for making SCN management decisions.
- **Education**: Need to transfer research information to producers effectively, such as improving producer awareness of problems, different susceptibility of varieties, etc, as farmers currently depend on seed companies for this information.

2. Phytophthora Root and Stem Rot *Phytophthora sojae*

Life Cycle:

- Phytophthora causes seed, seedling blight, root and stem rot of soybean when soils are saturated.

Distribution and Importance:

- This disease has been reported from major soybean production regions in the US, but also in Australia, Argentina, Brazil and more recently Republic of Korea and People's Republic of China.
- This disease appears to be getting more serious in recent years. It is worse on poorly drained soils.
- Losses due to Phytophthora can be substantial depending on the environment and the pathogen population. Historically, there have been individual fields with 100% yield loss during the 1950's through the 1970's. In Ohio, 20% and 40% of the fields in NW Ohio required replanting during 1997 and 2000, respectively; due mainly to *P. sojae*.
- Annual yield loss estimates (bu/A) from *P. sojae* for the North Central region were estimated to be 41, 54, 42, 26, and 40 million bushels for 1996, 1997, 1998, 1999 and 2000, respectively. In the southern US, losses due to *P. sojae* were estimated at 0.2% of a total of 1.5 million metric tons of harvested soybeans.

Non-Chemical Control:

- Single dominant host resistance genes (*Rps* genes) in soybean have been utilized extensively to manage *P. sojae*. *Rps* genes have had a "life expectancy" of 8 to 15 years. *P. sojae* populations in the US are comprised of many physiologic races with virulence to many of the *Rps* genes that are currently deployed in the US.
- Partial resistance (also termed field resistance, general resistance, rate-reducing resistance and tolerance in the soybean literature) has been shown to be effective against all races of *P. sojae*.
- PRR rating is used when selecting varieties (partial resistance) to plant.

Chemical controls

- Seed treatments (metalaxyl and mefenoxam) are also utilized in regions where *P. sojae* is an annual problem.

- Approximately 10-40% of seed is treated regionally. In Nebraska, seeds are usually not treated, whereas in Ohio, up to 40% of seeds are treated.   South Dakota has 15% of its seed treated, and the rest of NC region usually has less than 10% treated.
- Seed treatments are used in early-planted soybean more often than late-planted soybean. Current fungicide product registrations are needed for early-planted soybeans.

"To Do" List
Research

- **Research**: Researchers should continue to explore new products, especially seed treatments for Phytophthora.   Seed treatments (metalaxyl and mefenoxam) are utilized in regions where *P. sojae* is an annual problem.
- **Research:** IR-4 should investigate new seed treatments for control of water molds.

3. Sclerotinia Stem Rot *Sclerotinia sclerotiorum*

Life Cycle:

- Sclerotinia stem rot of soybean, commonly called white mold, is caused by *Sclerotinia sclerotiorum*, a long-lived soilborne fungus.

Distribution and Importance:

- The disease was commonly observed in Michigan, Minnesota and Wisconsin during the 1970's, but was rarely observed in the remainder of the North Central States until the 1990's. Starting in 1992, Sclerotinia stem rot was observed at epidemic levels in most North Central States and remains an annual threat to soybean production throughout the upper North Central region. Found in Michigan, N Illinois, Wisconsin, Minnesota, N Iowa, N Indiana, N Ohio. In Michigan it is one of most significant yield reducers
- The sudden increase of Sclerotinia stem rot is likely related to changes in cultural practices that promote dense crop canopies, changes in the genetic base of current soybean cultivars, and an increased incidence of pathogen infested seed.
- Yield loss caused by *S. sclerotiorum* is dependent on the percentage of the plant population killed by the pathogen, and how quickly individual plants die in relationship to reproductive development. Field trials indicate that for each 1% increment of plant mortality at the R6-7 growth stages, soybean yield is reduced 0.25 to 0.50 bushels per acre. Yield loss estimates due to Sclerotinia stem rot peaked at 957,000 metric tons in 1997.
- Yield loss is greatest in years of normal to below normal seasonal temperatures and yield potential is high for the crop.
- The severity of Sclerotinia stem rot is greatest in dense soybean canopies created by planting in narrow row widths, high plant populations, early planting, high soil fertility or other management practices that promote rapid and complete canopy closure.
- Sclerotinia stem rot is observed less in no-till fields compared to fields receiving some degree of tillage.
- Other rotational crops also have problems - dry beans and sunflowers.
- More of a problem in irrigated fields.
- Sclerotia of *S. sclerotiorum* are not toxic to humans and livestock.

Non-Chemical Control:

- The main control is variety selection (tolerance). Sclerotinia stem rot is managed by selecting soybean cultivars with the highest level of resistance and adjusting cultural practices to minimize environmental factors that influence disease development.
- Short-term crop rotation has a minimal effect on reducing the severity of Sclerotinia stem rot. However, a preceding crop of small grain, in contrast to corn, may have a moderate impact on reducing the risk of Sclerotinia stem rot.

Chemical Control:

- Thiophanate - methyl (fungicide) will reduce the incidence of Sclerotinia stem rot if applied during flowering and application methods allow the product to penetrate the lower regions of the canopy. An application of 2-6 oz/a of lactofen (herbicide) at the R1 growth stage has a suppressive effect on Sclerotinia stem rot.
- Cobra herbicide also has some effect on white mold. Its use would be specifically for white mold (not weed control).
- Fungicides are generally not used for control; too late to use fungicide when problem is apparent, also expensive.

"To Do" List
Research

- Researchers should develop a predictive model to alert producers when to control (with Topsin M) sclerotinia. This is especially needed with irrigated soybeans.
- *Coniothyrium minitans* is an example of a promising biological control agent that is a potential alternative for control of *S. sclerotiorum*. Further research on this agent would be helpful.
- Researchers need to investigate and develop more tools for control of resistance, i.e. how plant structure (large leaf vs. narrow leaf) affects severity.
- Some current research is investigating mapping one or more genes that confer physiological resistance to *S. sclerotiorum*. Application of a biotech approach to control of sclerotinia would be very helpful.
- Research is needed to investigate the efficacy of new dry bean and sunflower fungicides to see if they can be used on soybeans (other diseases such as downy mildew).

4. Sudden Death Syndrome of Soybean *Fusarium solani* f. sp. *glycines*

Life Cycle:

- Sudden death syndrome (SDS) refers to the foliar symptoms caused by a soil borne fungus.
- The fungus infects the root system within 2 to 3 weeks after planting and produces toxins that are translocated from the roots to the leaves. These toxins are thought to be responsible for the foliar symptoms.
- While SDS and stem canker have similar foliar symptoms, root symptoms of SDS are unique and are characterized by browning of the vascular tissue in the roots and lower stem with the pith remaining white.
- Root systems of infected plants are often reduced in size, and under cool moist conditions the taproots are covered by patchy spore masses that are dark blue to blue green in color.

- Foliar symptoms are often triggered by a cool, wet period just before or after flowering. Symptoms tend to first appear on lower leaves with yellow or sometimes white blotches appearing between veins. As the disease progresses, the yellow spots will turn necrotic with the mid-vein and major lateral veins remaining green. Eventually the leaflets may fall off leaving the petioles upright.

Distribution and Importance:

- It was first documented in the late 1960s in Arkansas and Tennessee and has since become a major concern for the U.S. North Central region. It has also been reported in Argentina, Brazil, Canada, and Thailand.
- Yield losses are the result of flower and pod abortion, and reduction of seed size and quality. Yield losses over an entire field may range from 1% to 50% depending upon the growth stage when symptoms appear. However, losses may approach 100% in severely affected areas. Regression analyses from several studies have shown a 6 to 10% yield loss associated with each 10% increase in disease.
- More of a problem in southern Minnesota, also more serious along eastern Iowa state line extending into east central Illinois. But SDS occurs throughout the NC Region and may be an economic problem depending on weather conditions.
- SCN can increase incidence of SDS.
- Tends not to be a problem in dry years.

Non-Chemical Control:

- Management options for SDS are few. Host resistance is the single best control measure. A few varieties have moderate to high levels of resistance and should be selected for fields with a history of SDS. Cool, wet soils at planting tend to promote infection by the fungus. Therefore, early plantings should be avoided.
- On fields with compaction problems or areas with poor drainage, deep tillage may prove beneficial in reducing SDS.

Chemical Control:

- No pesticide or seed treatment has proven effective for control of this disease.

“To Do” List:

Research

- Because some varieties are tolerant/resistant, it would be useful to have a method to evaluate new varieties - greenhouse and field assays, and to identify resistance genes within the genome.

5. Soybean Rust primarily *Phakopsora pachyrhizi* with some *P. meibomiae*

Distribution and Importance:

- Soybean rust can be a major limitation to soybean production. In 1995 it was reported in Hawaii, then in 1998 in Zimbabwe, in 2001 in South Africa, and in 2002 in Brazil and Paraguay. Rust appears to be on the move, making it an immediate threat to U.S. soybean production.
- Yield losses for the most part have been taken only on experimental plots. They have been demonstrated to vary greatly with some loss estimates as high as 80%. Soybean producers on several continents have stated that yield losses in their fields were as high as 50%. Losses are likely to be greatest when the fungus enters the crop early in its development as opposed to late pod-setting stage.

- Rust sporulation can build up quickly, so even if rust infects the crop during pod fill there potentially could be significant losses.
- Other conditions that may be conducive for rust would include high humidity and especially long dew periods. A crop that is grown in more arid conditions may not get as much rust, although if lush growth and canopy closure occurs early, the microclimate in the canopy may be beneficial to rust.
- The disease has the capacity to extend to all locations where soybean is grown with potential losses being greatest in higher production areas. It is unknown whether the rust fungus will exist through the seasons or whether it will have to be reintroduced from somewhere each season, and if the conditions for that reintroduction will be conducive for maximum spread.

Non-Chemical Control:

- Sentinel plantings of susceptible varieties or alternate hosts could be used for early detection of rust. Since soybean rust manifests primarily on maturing plants, the sentinel plantings should occur about 3 weeks before the commercial crop. This provides an opportunity to allow time to effect control of the pathogen in commercial plantings before the disease becomes epidemic.
- The most fruitful long-term management may well be the use of resistant varieties. Although the development of resistant soybean cultivars for mainstream use in the U.S. may be years away.
- A combination of both partial resistance and tolerance may have to be developed in breeding lines to reduce the impact of rust.
- Other long-term solutions also may include incorporating resistance from wild perennial Glycine species and from other sources using genetic engineering.

Chemical Control:

- Several fungicides are considered to be efficacious but none are registered for this use.
- Timing and cost effectiveness may be issues. Input costs are potentially $35-40 per acre.
- An early protectant application of fungicide will be needed around flowering time when sentinel plants are infected.
- Subsequent applications may be necessary as the crop matures and the disease begins to intensify.
- In Zimbabwe some farmers found a schedule of first applications 50 days after planting, then at 70 and 90 days after planting. In all cases, but especially in the first applications, it is most effective to apply the fungicides in such a manner that the lower canopy receives treatment.
- In areas of high rust severity, the first application is at first flowering and then two more applications in 21 day intervals thereafter. In areas with lower severity, the last application is not necessary.
- It is important that more than one fungicide be available in the event they are needed for soybean rust control so that resistance development is minimized.

“To do” List:

Research

- Resistance is of great importance to the industry. We are in lead time now, but we need to be ready as best we can. All efforts to accelerate preventative and prophylactic methods should be pursued.

- Industry must develop new compounds for rust control and research is needed on application techniques and different treatment scenarios.

Education

- Early identification is critical. The fungus is airborne, and has a life cycle of 4-9 days, and there are 4 different strains. Two with 20-40% losses, and two with 40-80%. The educational component on timing of fungicide treatments is important to producers as is timely access to diagnostic labs for accurate identification.

Regulatory

- The EPA must put registration of new and existing products for rust on the fast-track.

6. Soybean Viruses:

Bean Pod Mottle Virus (BPMV)

Life Cycle:

- Bean Pod Mottle Virus is vectored by the bean leaf beetle (BLB), and to a much lesser extent, other related beetles, such as the northern corn rootworm adult.
- The virus overwinters in the gut of the adult BLB and is transmitted from beetle regurgitant through surfaces freshly wounded by feeding. BPMV cannot be spread mechanically in the field.
- Soybean plants infected with BPMV produce deformed leaves with a mosaic pattern. High temperatures can affect the expression of the symptoms.
- Seed produced from infected plants may be marked with a dusky mottling or a bleeding hilum. Nonetheless, BPMV is transmitted at a low rate from discolored seed, typically less than 2%.

Distribution and Importance:

- Pod fill can be affected and yield losses greater than 50% have been reported.
- Soybeans for human food may be rejected due to seed coat discoloration.
- Soybean seed discolored by Soybean Mosaic Virus may be rejected by the buyer.

Non-Chemical Controls:

- Soybean cultivars are being screened for resistance or tolerance to the virus, but at this point most appear to be susceptible.
- Methods aimed at the control of the overwintering vector show the best promise for success, particularly targeting the emerging overwintering adult.
- BLB control to manage BPMV cannot be triggered by economic thresholds. Damage to the soybean crop through lost yield and visual seed quality are separate and distinct from losses due to defoliation.

Soybean Mosaic Virus (SMV)

- Seed produced from infected plants may be marked with a bleeding hilum and is typically transmitted at a rate of less than 5%.
- Soybean plants infected with SMV produce deformed leaves with a mosaic pattern, similar to injury from a growth regulator herbicide.
- SMV is vectored in a non-persistent manner by aphids.
- The potential for in-field spread of SMV may be much greater when soybean aphids are present because they colonize the crop, whereas other aphid species that have previously been known to transmit SMV are transient visitors to soybeans.
- Yield losses may be greater than 50%.

Non-Chemical Controls:

- Disease-free seed will limit the introduction of SMV to fields.
- Methods aimed at the control of the soybean aphid can effectively minimize SMV spread and damage.
- Vector management to minimize seed discoloration is more critical for soybeans marketed to the edible market.

VII. Soybean Insects and Slugs

1. Bean Leaf Beetles *Certoma trifurcata*

Life Cycle:

- Bean leaf beetles (BLB) are about 1/4-inch long and vary greatly in color from reddish brown to yellow. Usually they have black wing margins and two black spots on each wing cover. All have a black, triangular spot on the forward margin of the wings.
- Bean leaf beetles prefer to feed on the youngest plant tissue available. Adult feeding reduces pod set and seed quality. The economic threshold for bean leaf beetle is 25% or more defoliation throughout the field; 50% defoliation of the seedlings, or 25% defoliation during pod setting/filling or if pod damage is more than 10%.

Distribution and Importance:

- There are concerns about bean leaf beetles as a vector of bean pod mottle virus (BPMV) in the North Central region as it poses a challenge to setting economic thresholds for BLB management.
- In the last 2-3 years, ~30% of fields were treated in parts of southern MN and northern Iowa. In 2002, there were areas in northeast Iowa where nearly all fields were treated for BLB, but in the same year, little to none were treated in Illinois or the Dakotas. In that situation, about 25% of fields in northeast Iowa was treated in seedling stage for BPMV avoidance. In 2002, less than 2% of acres were treated in northeast Kansas.

Cultural Controls:

- Practices that promote healthy, vigorous soybean plants are effective in reducing the impact of all soybean defoliators. Soybeans grown under good conditions are remarkably tolerant to defoliation damage.
- Timely application of rescue treatments will reduce losses in yield and seed quality.
- Late plantings of soybeans will escape defoliation by overwintering bean leaf beetles and limit establishment of the first generation.
- Planting beans so that germination occurs between the two generations of adult beetles is helpful but not always practical.

Biological Controls:

- A tachinid fly that parasitizes adult beetles aids in controlling the bean leaf beetle in some states, however, little is known about natural enemies of the bean leaf beetle in the Midwest.

Chemical Controls:

- None needed for early season bean leaf beetles. Full coverage is not required when using systemic insecticides, although complete coverage is necessary for maximum efficiency when non-systemic insecticides are used. Drop nozzles may be needed for complete coverage if the canopy is large.

- Primary product of choice (for BLB alone): Pounce @ 2-4 oz./acre. Cheap and effective (coverage is an issue).
- Pyrethroids tend to be cheaper than organophosphates (OPs).
- Safety is a concern with field workers and REIs. Especially a concern with beans under irrigation in Kansas and Nebraska.
- In rotation with corn, some control of corn rootworms is desirable with BLB treatments. This is especially important in Illinois and other areas with the Western CRW variant in soybean.
- PreHarvest Intervals (PHIs) are a considerable concern for mid-season treatments, particularly with some of the pyrethroids. OPs (especially chlorpyrifos and dimethoate) tend to have shorter PHIs, and serve as a management option for producers.

Organophosphates

Chlorpyrifos Lorsban 4E @ 1 to 2 pint per acre

- PHI =28d
- REI =24h
- Maximum application of 6pt/season
- Lorsban is good for an OP alternative

Dimethoate Cygon 400 @ 1 pint per acre,

- PHI =21d (grain)
- REI =48h

Methyl parathion Penncap-M @ 2-3 pints

- PHI =20d
- REI =4d
- Maximum of 2 applications per season

Pyrethroids

Lambda-cyhalothrin. Warrior

- REI =24h
- PHI =45d

Esfenvalerate Asana XL 0.66EC @ 4.8 to 9.6 ounces per acre,

- PHI =21d
- REI =12h
- Highly disruptive to mite populations

Permethrin Ambush 2EC @ 3.2 – 6.4 ounces per acre

Permethrin Pounce 3.2EC @ 2-4 ounces per acre,

- PHI =60d
- REI =12h
- Maximum of 0.4 lb ai/a per season
- Pounce is cheap and effective

Zeta-cypermethrin Mustang

- Mustang has good residual activity
- PHI =21d
- REI =12h

Carbamates:

Carbaryl Sevin (various) 0.5 to 1.5 lb ai/a

- PHI =45d

- REI =12h
- Toxic to beneficials and mites

Methomyl Lannate 1.8L @ 0.5 – 1 pint per acre,

- PHI =14d (for grain)
- REI =48h
- Highly toxic to mite predators
- Maximum of 3 applications per season

Thiodicarb Larvin 3.2F @ 18-30 ounces per acre

- PHI =28d
- REI =48h
- Maximum application 3 lb ai/a per season

"To Do" List:

Regulatory

- Increasing the REI for pyrethroids could be a hardship for producers with workers in the field, irrigation workers, and with researchers in plots.
- Some OPs are needed in the toolbox so that we can rotate insecticide classes, and to stem potential outbreaks of specific insect species like spider mites. In addition, supplies of individual products may run out during a pest outbreak, so other products are needed to fill in.

Research

- Research bean leaf beetles as a vector of bean pod mottle virus and the dynamics of the spread of bean pod mottle virus.

2. Soybean Aphid *Aphis glycines*

- Soybean aphids suck plant juices and in heavy infestations leaves covered by aphids are wilted or curled. The aphids also feed along the stems. Upper leaves tend to have the most aphids, while lower leaves may be sticky and black with sooty mold.
- As aphids feed, they secrete a sweet substance called honeydew. The honeydew drops onto lower leaves, and provides an excellent place for the mold to grow.
- It does not inject toxins that cause hopperburn or growth-regulator-type injury on leaves.

Distribution and Importance:

- In southeast Minnesota (Houston and Fillmore Counties) in 2001, 30-50% of producers sprayed, and many situations resulted in 10-15% yield savings.
- 2001 was a big incidence year of this new pest. In 2002, the incidence was markedly less across the region. Weather (temperature and dryness), beneficial insect population establishment, and other factors were likely the reason.
- Aphids like cool and moist conditions.
- Soybean aphid also is a vector for Soybean Mosaic Virus.

Non Chemical Control:

- Recommendations are not leaning towards insecticide use to control the soybean aphid. First, the fields are often loaded with biocontrol agents -- predators, parasitoid wasps, and pathogenic fungi that infect and kill aphids. The pathogens are doing a particularly good job of killing aphids, and populations crash in a matter of days.
- Second, it is difficult to spray fields and get adequate coverage without physically damaging beans.
- And finally, the price of soybeans probably does not warrant spending money to spray,

unless the infestation is tremendous.

Chemical Control:

- Not used with regularity.

Organophosphates

Acephate Orthene 75S @ 0.67 pounds per acre
- PHI =14d
- REI =24 h

Chlorpyrifos Lorsban 4E @ 1 to 2 pint per acre
- PHI =28d
- REI =24h
- Maximum application of 6pt/season

Dimethoate Cygon 400 @ 1 pint per acre,
- PHI =21d (grain)
- REI =48h

Methyl parathion Penncap-M @ 2-3 pints
- PHI =20d
- REI =4d
- Maximum of 2 applications per season

Phorate Thimet 20G applied as banded soil treatment
- REI =48h
- PHI =NA
- Must not come in contact with seed
- Do not apply if metribuzin has been applied

Chlorinated hydrocarbon

Lindane (various) (seed treatment)
- REI =12h
- PHI =NA

Pyrethroids

Lambda-cyhalothrin Warrior
- REI =24h
- PHI =45d

Esfenvalerate Asana XL 0.66EC @ 4.8 to 9.6 ounces per acre
- PHI =21d
- REI =12h
- Highly disruptive to mite populations

Permethrin Ambush 2EC @ 3.2 – 6.4 ounces per acre
Pounce 3.2EC @ 2-4 ounces per acre
- PHI =60d
- REI =12h
- Maximum of 0.4 lb ai/a per season

Carbamates:

Carbaryl Sevin (various) 0.5 to 1.5 lb ai/a
- PHI =45d
- REI =12h
- Toxic to beneficials and mites

Carbofuran Furadan 4F @ 0.11 to 0.25 lb ai/a

- PHI =21d
- REI =14d
- Maximum of 2 applications per season

Methomyl Lannate 1.8L @ 0.5 – 1 pint per acre,

- PHI =14d (for grain)
- REI = 48h
- Highly toxic to mite predators
- Maximum of 3 applications per season

Thiodicarb Larvin 3.2F @ 18-30 ounces per acre

- PHI =28d
- REI =48h
- Maximum application 3 lb ai/a per season

Growth Regulators:

Dimilin Diflubenzuron 25W or 2L 0.125 to 0.25 lb ai/a

- PHI =21d
- REI =12h
- Slow acting, inhibits molting, may take 3 to 7d to reduce populations
- Minimum re-application interval is 30d

“To Do” List:

Research

- Producers need to know more about soybean aphid population dynamics and yield losses.
- Researchers are encouraged to look at the relationship between populations and some specific management practices. Non-empirical observations reported a higher incidence of SBA in Roundup-ready beans, no-till, and low-K+ fields.
- Producers need solid information about economic thresholds, product rates, treatment timing and its effect on beneficial insects.

Education

- As research results are generated, there is a need to make that information available in a timely manner.

Current efforts:

- Currently, there are several collaborative projects examining the distribution and range of host plants.

3. Two-spotted Spider Mites

Distribution and Importance:

- Spider mites are common in the Midwest and are an occasional economic pest.
- Heavy infestations kill the leaves and result in "scorched" areas in the field.
- Mite outbreaks are often associated with drought conditions. Heavy rain will often knock back populations.
- Spider mite outbreaks are most often associated with dry conditions. In Nebraska there is usually some spider mite infestation even under irrigation each year.

Chemical Control:

- If a problem with mites is identified early, treatment of hot spots may suffice.
- If mites have spread across the field then thresholds are: pre-bloom- 40% damage; bloom to podfill - 15% damage; and podfill to early maturity - 25% damage (damage is when

leaves are discolored).

- Most pyrethroids are ineffective against spider mites.
- In Illinois, 70-80% of fields were sprayed in 1988. In some areas of the Midwest, some fields are sprayed every year. All in all there is some spraying each year somewhere in the North Central region.
- Dimethoate is the primary product labeled for use on spider mites. Lorsban is the only other product labeled.
- In heavy outbreak situations, there are often supply problems. Some of that is because of re-treatment as the population rebounds sometimes 2-3 times.

Biological Controls:

- There is a fungal pathogen that kills mites under warm, humid conditions.

Chemical Controls:

Organophosphates

Chlorpyrifos Lorsban 4E @ 1 to 2 pint per acre

- PHI =28d
- REI =24h
- Maximum application of 6pt/season

Dimethoate Cygon 400 @ 1 pint per acre

- PHI =21d (grain)
- REI =48h

Pyrethroids

Lambda-cyhalothrin Warrior

- REI =24h
- PHI =45d

"To Do" List:

None listed

4. Grasshoppers *Melanopus spp.*

Life Cycle:

- Mature grasshoppers mate and feed on crop plants. About 2 weeks later, females begin to deposit clusters of eggs in the soil. During this process, a glue-like secretion cements soil particles around the egg mass, forming a protective "pod." Each pod may contain 25 to 150 eggs, depending on the species of grasshopper. Grasshoppers that deposit masses containing fewer eggs usually lay more pods to compensate. Each female may produce 300 eggs.
- Swarms of grasshoppers usually adopt a specific area as their breeding ground and lay all eggs in that vicinity. Most economically important grasshopper species complete only one generation each year. Red-legged grasshoppers, however, have at least two annual generations.

Distribution and importance:

- Grasshoppers are frequently a problem in the Great plains states (KS, NE, SD, ND) and western Minnesota, Iowa and Missouri. Elsewhere, grasshoppers are an occasional pest of soybean.
- Conservation Rerserve Program acres (CRP) (in MO) planted to brome and/or red clover can be the source of sizeable grasshopper populations that can migrate into adjacent fields. It was noted that CRP in native grasses did not seem to create a problem.

- The adults and nymphs damage the plants by chewing them thereby defoliating the plants.
- If two or more years of dry weather precedes the growing season, conditions will likely favor infestation and damage.
- Other conditions favoring damage include undisturbed grassy sites next to fields, which is preferred for egg laying, and dry, warm weather often enhances survival of nymphs.
- The threshold for grasshoppers in soybean fields is 25% or more defoliation.

Biological Controls:

- A fungal pathogen can kill many eggs and nymphs under wet spring conditions.
- There are also many animals such as birds, rodents and amphibians that eat grasshoppers.

Chemical Controls:

- Dimilin is not often used, but is effective and inexpensive.
- Treatment typically is made to field edges and grassy borders, terrace backslopes.

Organophosphates

Acephate Orthene 75S @ 0.67 pounds per acre
- PHI =14d
- REI =24 h

Chlorpyrifos Lorsban 4E @ 1 to 2 pint per acre
- PHI =28d
- REI =24h
- Maximum application of 6pt/season

Dimethoate Cygon 400 @ 1 pint per acre
- PHI =21d (grain)
- REI =48h

Methyl parathion Penncap-M @ 2-3 pints
- PHI =20d
- REI =4d
- Maximum of 2 applications per season

Pyrethroids

Lambda-cyhalothrin Warrior
- REI =24h
- PHI =45d

Zeta-cypermethrin Mustang
- REI =12h
- PHI =21d

Esfenvalerate Asana XL 0.66EC @ 4.8 to 9.6 ounces per acre
- PHI =21d
- REI =12h
- Highly disruptive to mite populations

Carbofuran Furadan 4F 0.11 to 0.25 lb ai/a
- PHI =21d
- REI =14d
- Maximum of 2 applications per season

"To Do" List:

Research -

- Need research on the effects of biological control agents/predators on grasshoppers.

5. Other Insects

Soybean stem borer:
- Problem in Kansas, western Missouri, southern Nebraska, northern Oklahoma and South Dakota.

Japanese Beetles:
- Problem in Michigan, Illinois, Indiana, Ohio, eastern and central Iowa. The suite of insecticides effective against bean leaf beetle also control Japanese Beetle.

Slugs:
- Problem in Ohio and Indiana, especially in no-till. Not an insect pest but a mollusk. Slugs occur in heavily manured areas. Occasional pest in several areas. Wet and cool conditions in fields; also where seed slots don't close and slugs can attack.

"To Do" List:

Research
- We need cumulative thresholds developed on a product basis.
- Western corn rootworm (WCR) - need to understand the biology of the western variant to give rationale for control in corn-soy rotations. Are WCR adults carriers of BPMV and other soybean virus diseases?

Research & Education
- Overall - Need university researchers, consultants and producers to work together closely with on-farm research and demonstration.

Education
- Coalition between land grant institutions, consultants, suppliers, dealers and registrants to promote resistance management and effective pest management systems.

VIII. Soybean Weeds

General Information:
- 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.
- As many as 30 different plant species are widely found as weeds in soybean fields in the North Central region. For the purposes of this strategic plan, the workshop participants identified "risk drivers" for herbicide applications and weed management decisions. Some, such as waterhemp, cocklebur, velvetleaf and foxtails qualified as "risk drivers" across the Midwest, whereas others such as shattercane, or woolly cupgrass may drive herbicide application on a regional basis or only under certain types of production systems (e.g. continuous soybean, soybean in rotation with sorghum, etc.).
- Finally, before a herbicide is selected; the presence of, or tendency to develop, herbicide resistance must be considered. 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 genetic or physical characteristics. Some of these characteristics include non-self-pollination (outcross),

prolific seed production (seedling survival), 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).

Non-Chemical Control:

- Tillage remains a principal means of controlling or managing weeds, especially perennial weeds.
- Moldboard plowing, field cultivators, and secondary tillage such as row cultivation and rotary hoeing are still widely used. In regions of northern Iowa, southern Minnesota and Wisconsin, and in South and North Dakota the tillage that is used to enhance warming of the soils early in the season contributes to weed management.
- The constant dilemma that producers face is that most tillage methods contribute to soil erosion and may not be a sustainable practice on most fields.
- In areas where conservation tillage or no-till predominate, as in Ohio and Indiana, tillage of any kind is not often considered for weed control.
- Tillage is closely related to drainage, soil type, slope and temperature.
- Producers retaining non-GMO soybeans retain use of cultivation as a significant weed control management tool.
- Plowing is being used by some for weed management in central Illinois, especially for woolly cupgrass, where up to 20-30% of the acres may be so treated. Tillage is also used for profit (yield), insect and disease control, and nutrient and manure stratification. In areas where plowing has less impact on the environment, producers are sometimes returning to the use of the plow.
- Crop rotation is another means of controlling weeds. Although much of the Midwest is primarily a cycle of field corn and soybean planted year after year, in some areas extended rotations include alfalfa, wheat, oats, sunflowers, sorghum, or perhaps sweet corn, popcorn, snap beans or dry beans grown for processing. An extended crop rotation cycle may allow a rotation of herbicides or variations in tillage that will minimize many weeds.
- Row width selection may also contribute toward weed management.
- Narrow-row, or drilled soybean, provides a means of quickly establishing a crop canopy which shades inter-row regions and inhibits the growth of many weeds.
- However, some weeds are nearly immune to this, especially perennials, and narrow row widths may exclude the use of cultivation as a means of controlling weeds.
- Sometimes 30-inch rows are used due to harvesting equipment or to facilitate herbicide banding.
- Significant minority of producers use cultivation and rotary hoe where there are 30-inch rows.
- While equipment and field sanitation are considerations for all farmers, it has not been practical for most producers to adopt as a matter of principal concern. Movement of weed seed from neighboring fields via wind or harvest or tillage equipment is difficult to guard against.
- Organic producers may consider delaying planting date to allow further weed germination and tillage for control.

"To Do" List for All Weeds
Research

- Need to maintain research on non-GMO plant breeding and herbicides.
- Chemical companies should continue researching and registering new chemistries to provide additional tools for problem weed management. It is particularly important to have the herbicides necessary where resistant weeds have developed.
- Evaluate the role of temperature, humidity, and time of day on post-applied product efficacy.
- Determine how best to control weeds in wheel tracks.
- Improve efficacy and control drift of post applied herbicides (application technology-spray tips and various spray systems, ground and air).
- Research additives to tank mixes; which ones work well and how do they work.
- Research weed shifts due to lack of tillage and weeds moving into fields from road sides.

Education

- Need university researchers, consultants and producers to work together closely with on-farm research and demonstration. Also develop a coalition between land grant universities, non-governmental organizations, consultants, suppliers, dealers and registrants to promote resistance management and effective pest management systems.

Regulatory

- Maintain 2,4-D as a burndown.
- Need to keep atrazine use in corn prior to soybeans for overall weed management in rotations.
- Labels of additives should contain all ingredients.

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 (two weeks) or very long (30-50 yrs) periods before germination.
- Weed seeds are distributed by wind, rain, birds, and mechanical harvesting equipment.

Distribution and Importance:

Annual grasses infest approximately 98% of all soybean acres. Many of these are controlled with pre-emergence herbicide applications and tillage.

- While usually not as competitive as broadleaf weed species on a plant for plant basis, annual grasses can reduce crop yields when significant populations are present.
- In the most western portion of the North Central region sandbur dictates weed management.
- Woolly cupgrass is also a factor in grower weed management decisions. This is particularly true in central Illinois, southern Wisconsin and southern Minnesota, southeast South Dakota, and northern Missouri. However, controlling this weed also controls foxtails.
- Foxtails are the predominate grass weed but easily controlled with current herbicides.
- Crabgrass is especially troublesome on sandy soils throughout the region.

- Shattercane can be a problem in Illinois, Indiana, Kansas and Nebraska, but more so in Missouri.
- Wirestem muhly affects weed management decisions in northern Illinois and northeast Iowa.
- Fall panicum is also a factor affecting control decisions in Ohio, but still less than foxtails.

Key "risk drivers":

a. 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 soybean 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 pre-emergence grass herbicides. These provide early season control, reducing early season competition.

b. Woolly cupgrass (*Eriochloa villosa*)

Woolly cupgrass is a relatively new and potentially 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 tolerance to most herbicides commonly used for control of annual grasses in soybean.

c. 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, and fall panicum is most often a problem in reduced or no-till fields whose undisturbed soils are favorable for germination. Fall panicum has shown some tolerance to atrazine, and can be a serious grass weed in the region.

d. 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.

e. 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 areas.

f. 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 the mouth of feeding cattle.

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

A warm season grass most often troublesome in the southern region of the Corn/Soybean Belt. 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 holes remain in the canopy.

Tillage and row cultivation also help control.

h. Shattercane (*Sorghum bicolor*)

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

i. Wild oats (*Avena fatua*)

Wild oats are virtually indistinguishable from domesticated oats (*Avena sativa*). The seed heads of wild oats disperse naturally or when they are impacted by the combine, releasing the seeds to the soil rather than being collected in the combine. Wild oats are difficult to control with herbicides because they are closely related to the crop.

Chemical Weed Control (Herbicides):

Root/shoot inhibitor (Acetamides): Dual, Outlook, Lasso, Harness/Surpass

- High rates have been found necessary for control of some species but may not be economical
- Doesn't control shattercane or sand bur or wild oats adequately
- These products work fairly consistently
- Used in herbicide rotations (mode of action)
- No known resistance problems
- Useful in non-GMO systems
- Crop safety good
- No rotational issues
- Provides some residual control

Mitosis inhibitor (Dinitroanilines): Prowl, Treflan

- Economical
- Residual control of annuals
- Has broad spectrum (controls some broadleaf weeds too)
- Used in herbicide rotations (mode of action)
- Partial shatter cane control
- Some crop injury - diseases set in
- Some carryover injury
- Treflan has to be incorporated, doesn't work in no-till systems
- Some resistance issues (foxtails, other broadleaf weeds)

Bleaching: Command

- Off-site drift a concern
- Carryover to follow crop a concern
- Expensive relative to some other herbicides
- Erratic control in some situations, need high rates for good efficacy
- Requires shallow incorporation for best efficacy
- Direct crop injury not a concern
- Broad range of efficacy when applied properly to annual grasses and broadleaves
- Useful on non-GMO varieties, good alternative to roundup system

EPSP synthase inhibition: Glyphosate

- Highly efficacious and broad spectrum
- Inexpensive
- Low rates can also be effective
- Timing flexibility
- No carry-over or residual activity
- No ground water issues
- Drift and misapplications are a concern
- Some weeds have developed tolerance/resistance
- Requires special genetics (GMOs) for post emergence application with additional expense
- Wide price fluctuation in product
- Soybeans (non-gmo) not eligible for premium price
- Antagonism with broadleaf herbicides is possible

ALS inhibitors - Pursuit, Scepter, Raptor, Classic

- Crop injury a concern
- Carry-over injury to follow up crop a concern
- Antagonized by tank mix partners, esp with grasses
- Low to good efficacy on grasses, varies greatly by product within this group
- Low use rates
- Environmentally safe
- Time of application flexibility
- Residual effect

Aryloxyphenoxypropionates: Assure, Fusilade, Poast, Select

- Effective on volunteer corn, including RR corn
- Good grass rescue (when grasses are beyond control by other products)
- Differences in efficacy among products exist within this group
- Difference among products for crop injury exists within this group
- Weed resistance in foxtail and wild oats - (Assure, Fusilade and Poast)
- Antagonized by broadleaf herbicides
- Performance diminished under drought conditions

Other: Gramoxone

- For early burn-down only
- Perception of toxicity to humans discourages use

"To Do" List
Research

- Researchers should evaluate which grasses will develop tolerance or resistance to glyphosate, will there be approval of tank mixes to control these grasses.
- Researchers should determine the effect of row widths and impact of reduced rates and treatment frequency of soybean herbicides.
- Researchers should evaluate the frequency of applications and its effect on resistant

weeds - weed shift studies.
- Evaluating the rates of glyphosate (efficacy of reduced rates) vs weed growth size vs environmental conditions would be useful. Determining how product formulation and species diversity affect these would also be helpful.
- Producers need to know how to alleviate antagonism in tank mixes under variable environmental factors with products such as Select, Fusilade, Assure, Fusion.

Education
- Communication of weed shift study results to producers when available is important.
- Educate producers on rates of glyphosate uses (efficacy of reduced rates) vs weed growth size vs environmental conditions.

2. Perennial grasses and sedges

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 soybean 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.
- Quackgrass factors into weed management decisions in southern Minnesota, North Dakota, Wisconsin, Michigan, and northern Illinois.
- Johnsongrass is a weed of concern south of I-70, and a major weed in river bottoms, in Kansas, and from St Louis to St Joseph, Missouri.
- Yellow nutsedge is an opportunistic weed held at bay by current herbicides, more of a problem in southwest Iowa and throughout Kansas, and in high peat soils.
- Horsetail is a problem in some no-till fields. It is very hard to control as there are no herbicides that are effective.

Key “risk drivers”:

a. Quackgrass (*Elytrigia repens*)

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

b. 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.

c. 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/Soybean Belt.

d. 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.

e. Horsetail (*Equisetum* spp.)

A plant with an ancient genome, horsetails favor wet soils with high organic matter. Though they seldom cause yield reductions, they are very difficult to control with herbicides and can become a serious problem in localized areas.

Chemical Control:

Root/shoot inhibitor (Acetamides): Dual, Outlook, Lasso, Harness/Surpass

- High rates have been found necessary for control of some species though they may not be economical
- Used in herbicide rotations (mode of action)
- No known resistance problems
- Useful in non-GMO systems
- Crop safety good
- No rotational issues
- Provides some residual control

Mitosis inhibitor (Dinitroanilines): Prowl, Treflan

- Economical
- Residual control of annuals
- Used in herbicide rotations (mode of action)
- Some crop injury - diseases set in
- Some carryover injury
- Treflan has to be incorporated, doesn't work in no-till systems
- Some resistant weeds (foxtails, other broadleaf weeds)

Bleaching: Command

- Off-site drift a concern
- Carryover to follow crop a concern
- Expensive relative to some other herbicides
- Erratic control in some situations, need high rates for good efficacy
- Requires shallow incorporation if incorporated for good efficacy
- Least direct crop injury
- Broad range of efficacy when applied properly to annual grasses and broadleaves
- Useful on non-GMO varieties, good alternative to Roundup system

EPSP synthase inhibition: Glyphosate, Glufosinate

- Highly efficacious and broad spectrum
- Inexpensive

- Low rates
- Timing flexibility
- No carry-over or residual
- No ground water issues
- Drift and misapplication is a concern
- Developing resistance a concern
- Requires special genetics (GMOs) for post emergence application (Seed expense)
- Wide price fluctuation of product
- Soybeans (non-gmo) not eligible for premium price
- Controls Johnsongrass with effort, takes multiple treatments
- Most effective perennial grass control available
- Marginal on nutsedge
- Multiple applications necessary on perennial grasses
- Less effective if sun isn't shining

ALS inhibitors - Pursuit, Scepter, Raptor, Classic

- Crop injury a concern
- Carry-over injury to follow up crop a concern
- Weed resistance is common and widespread
- Antagonized by tank mix partners, esp with grasses
- Low use rates
- Environmentally safe
- Time of application flexibility
- Residual effect
- Low efficacy on perennial grasses, varies greatly within this group
- Classic (Chlorimuron) provides control of yellow nutsedge

Aryloxyphenoxypropionates: Assure, Fusilade, Poast, Select

- Good grass rescue (when other controls fail)
- Difference among products in group in efficacy
- Difference among products in crop injury
- Antagonized by broadleaf control tank mix partners
- Performance diminished under drought conditions

Other: Basagran, Gramoxone

- Basagran is good on yellow nutsedge

"To Do" List

Research

- Research herbicides for control of Johnsongrass in rights-of-way (reduce movement to fields).
- Research is needed to determine which herbicides may control of horsetail.
- Research application timing - efficacy of spring vs fall application of foliar applied herbicides.

Regulatory

- Find ways to encourage State control of Johnsongrass along rights-of-way.

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 (two 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.
- The primary broadleaf weed management decision drivers are giant ragweed, common sunflower, marsh elder, nightshade, pigweeds, waterhemp, common ragweed, kochia, morning glory, jimsonweed.
- Kochia is primarily in western Illinois and all states to the west.
- Cocklebur, velvetleaf, waterhemp and common sunflower are major concerns for Missouri, Nebraska and western Iowa.
- Giant ragweed, lambsquarter, cocklebur, velvetleaf, waterhemp, and pigweed are the principal decision drivers for Illinois, Indiana, Ohio, southern Wisconsin and Michigan.
- Nightshade is a problem for seed bean producers. Controlled in non-seed fields by current herbicides.
- Pennsylvania smartweed problem in wet springs, tends to be spotty.
- Morningglory is becoming weed of concern in Illinois. It is hard to control in soybean, therefore there is a need to control it in corn while in rotation.
- Palmer Amaranth is a decision driver in Kansas, the “bootheel” region of Missouri, and eastern Nebraska.
- In North Dakota, jimsonweed, giant ragweed, and velvetleaf are not decision drivers. Common ragweed, nightshade, kochia, marsh elder and wild buckwheat are decision drivers in this area.

Key “Risk Drivers”:

a. Nightshade (*Solanum spp*)

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/Soybean Belt, severe infestations in individual fields do occur. Tillage and row cultivation are effective for early, newly emerged seedlings.

b. 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 control cocklebur establishment.

c. 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 40F to 94F, which suggests early germination capabilities. Survival is favored by rains that dilute or leach herbicides from the soil surface.

d. 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.

e. 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.

f. 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. Because jimsonweed is susceptible to most herbicides its severity has decreased significantly in recent years.

g. 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.

h. Morningglory (*Ipomoea* spp.)

Tall morningglory and ivyleaf morningglory are the two major annual morningglory species found in the Corn/Soybean 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 most anywhere in the state. 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.

i. 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.

j. 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.

k. Velvetleaf (*Abutilon theophrasti*)

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

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

Common waterhemp is a native species and is a serious weed problem throughout the Corn/Soybean 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.

m. Wild Buckwheat (*Polygonum convolvulus*)

Although not prolific across the region this weed can be a problem across the lower portion of the corn/soybean belt. It is a weed best adapted to moist fertile soils. The weed has a vining habit.

n. Common sunflower

Common sunflower is more common in the western portion of the corn/soy belt but can be found throughout the region. It germinates from deep in the soil and may escape control by herbicides that are not thoroughly incorporated into the soil.

o. Marsh Elder (*Iva xanthifolia*)

A plant that favors wet, low lying fields. Not a significant problem throughout the region but can be a problem in some areas.

p. Bur Cucumber - Missouri, Nebraska, Illinois, parts of South Dakota

Bur cucumber is more common is river bottoms and in areas where birds and other animals commonly move the seed into cropping areas. The plant has a vining habit and can be a serious problem if infestations are not adequately controlled.

Chemical Control:

Photosystem I inhibitor (Triazines): Metribuzin

- Increases activity for some other materials
- Some residual activity
- Alternate mode of action is useful for resistance management
- Crop tolerance is a concern especially on high pH soils
- Resistant weeds have developed

Root/shoot inhibitor (Acetamides): Dual, Outlook, Lasso, Harness/Surpass

- For some of the harder to control species the higher rates necessary may not be economical
- These products work fairly consistently

- Used in herbicide rotations (mode of action)
- No known resistance problems
- Useful in non-GMO systems
- Crop safety good
- No rotational issues
- Provides some residual control
- Effective only on small seeded broadleaf weeds, especially on water hemp - amaranthus spp.
- Helps control nightshade

Mitosis inhibitor (Dinitroanilines): Prowl, Treflan

- Economical
- Residual control of annuals
- Has broad spectrum (controls some grass weeds too)
- Used in herbicide rotations (mode of action)
- Some crop injury - diseases set in
- Some carryover injury concerns
- Treflan has to be incorporated, doesn't work in no-till systems
- Some resistant weeds (foxtails, other broadleaf weeds)
- Sonalan has enhanced control of wild buckwheat
- Fairly effective control of kochia

Bleaching: Command

- Off-site drift a concern
- Carryover to follow crop a concern
- Expensive relative to some other herbicides
- Erratic control in some situations, need high rates for good efficacy
- Requires shallow incorporation for good efficacy
- Least direct crop injury
- Broad range of efficacy when applied properly to annual grasses and broadleaves
- Useful on non-GMO varieties, good alternative to Roundup system
- Very weak on waterhemp and other amaranthus
- Very narrow spectrum of control
- In combination with other herbicides works well on giant ragweed
- Excellent control on velvetleaf
- Good on cocklebur

EPSP synthase inhibition: Glyphosate, Glufosinate

- Highly efficacious and broad spectrum
- Inexpensive
- Low rates
- Timing flexibility
- No carry-over and no residual
- No ground water issues
- Drift and misapplication is a concern
- Weeds have developed resistance

- Requires special genetics (GMOs) for post emergence application (Seed expense)
- Wide price fluctuation of product
- Soybeans (non-GMO) not eligible for premium price
- Less effective if sun isn't shining
- Less effective on giant ragweed that is infested with stalk borer
- Weeds in wheel tracks often escape control
- Poor control of climbing milkweed, morning glory, kochia and smartweed, nightshade, wild buckwheat, lambsquarters, prickly sida
- Not as efficacious on broadleaf weeds as grasses
- Size of weeds is critical
- Generally requires ammonium sulfate for good control although soy oil is sometimes used instead of ammonium sulfate.

ALS inhibitors - Pursuit, Scepter, Raptor, Classic
- Crop injury a concern
- Carry-over injury to follow up crop
- Weed resistance is common
- Antagonized by tank mix partners, esp with grasses
- Environmentally safe
- Time of application flexibility
- Residual effect

Protoporphyrinogen oxidase inhibitors: Blazer, Cobra, Reflex, Resource
- Good for waterhemp
- Crop injury a concern
- Carry-over with Reflex
- Resistant waterhemp showing up
- Good control of amaranthus (as a resistance management tool)
- Resource good on velvetleaf
- Blazer good on ragweed
- Some benefit in suppressing white mold - esp Cobra
- Some signs of resistance in waterhemp in pockets throughout the Midwest

Other: Basagran, Gramoxone, Glufosinate, 2,4-D
- Gramoxone early burn-down
- Basagran good on velvetleaf
- Basagran has good crop safety
- Basagran has no carryover
- Gramoxone - perception of toxicity
- Gramoxone weak on annual smartweed
- Basagran inconsistent in sunflower control
- Basagran has a narrow window of application
- Basagran is expensive
- 2,4-D Burndown is very effective and necessary to retain
- 2,4-D Burndown may possibly cause some crop injury
- 2,4-D fall applications possible

“To Do” List
Issues are noted under “All Weeds”

4. Perennial broadleaf weeds
Biology and life cycle:
- While perennial weeds do produce seeds, the majority of plants listed propagate through vegetative means. For example, Canada thistle’s underground structures supporting vegetative reproduction are roots.
- 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 soybean production. Since most perennial broadleaf weeds do not tolerate tillage, these weeds are more of a problem in reduced tillage and no-till operations.
- Currently all of the weeds listed below could be considered a more serious problem than they were five to 10 years ago.
- Milkweed, hemp dogbane, Canada thistle are the principal regional drivers of weed management decisions.
- Pokeweed can be a weed decision factor in conservation tillage in northern Illinois, Michigan, NW Missouri, Indiana, southern Iowa.

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, such as pokeweed, hedge bindweed, and 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.

Key “Risk Drivers”:

a. Common Milkweed (*Asclepias syrica*)

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 two 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.

b. 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.

c. 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.

d. 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/Soybean Belt is usually most severely infested with dogbane. Tillage can reduce dogbane infestations, but is ineffective once populations are established.

e. Swamp smartweed (*Polygonum amphibium*)

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 its similarity to Pennsylvania smartweed, an annual, many producers incorrectly identify this weed.

f. 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.

g. Pokeweed (*Phytolacca americana*)

Pokeweed is becoming more important as a weed throughout the eastern section of the Corn/Soybean Belt. It tends to be hard to kill and severe infestations can cause contamination of grain that can result in its rejection by elevators.

h. Dandelion (*Taraxacum officinale*)

Common throughout the region, this weed shows up in no-till fields in every state. Although herbicides will control newly germinating dandelions easily, more mature plants can be difficult to control and reseed areas early in the season.

i. Trumpet Creeper (*Campsis radicans*)

Trumpet creeper is a woody vine that is common is low lying areas and river bottom fields. Tillage is effective for control but not practical on many highly erodible soils.

j. Virginia Creeper (*Parthenocissus virginiana*)

Virginia creeper is a vining plant common to forest soils.

Chemical Control

Bleaching: Command

- Use command on soybeans and then banvel on corn to control hemp dogbane

EPSP synthase inhibition: Glyphosate

- Highly efficacious and broad spectrum
- Inexpensive
- Low rates
- Timing flexibility
- No carry-over and no residual
- No ground water issues
- Drift and misapplication is a concern
- Weeds are developing resistance
- Requires special genetics (GMOs) for post emergence application (Seed expense)
- Wide price fluctuation
- Soybeans (non-GMO) not eligible for premium price
- For many perennials multiple applications are necessary for marginal control
- Control often limited to spot treatments
- Can wipe dogbane and milkweed and pokeweed

ALS inhibitors - Pursuit, Scepter, Raptor, Classic
- Crop injury a concern
- Carry-over injury to follow up crop a concern
- Weed resistance is common
- Antagonized by tank mix partners, esp with grasses
- Low use rates
- Environmentally safe
- Time of application flexibility
- Residual effect
- Synchrony effective on pokeweed and may have marginal but long term effects on other perennial broadleaf weeds

Other 2,4-D, Banvel
- 2,4-D effective in fall on dandelions and repeated treatments for Canada thistle
- Can be used before and after crop
- Banvel can be used in fall

"To Do" List
Research
- Need to develop system approach for control of perennial broadleaf weeds, to include tillage and conventional pesticide use.
- Need to develop methods of control for trumpet creeper, Virginia creeper, pokeweed, mulberry, cottonwood, and soft maple.
- Researchers should develop and evaluate economic thresholds for perennial weeds.

5. Winter Annual Weeds and Cover Crops
- Winter annuals seem to be more of a problem in last few years and more of a control concern to producers (esp. in no-till).
- Producers have gotten away from relying on residual herbicides.

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/Soybean Belt, while others such as bluegrass and bromegrass tend to be more of a problem across the southern section of Missouri, Illinois, Indiana and Ohio. Mustard, chickweed, henbit, and marestail (no-till esp) are prevalent across the region.
- In Ohio red dead nettle is also present.
- Horseweed (Marestail) is confirmed as glyphosate resistant.
- Wild lettuce is a decision driving factor in northwest Missouri.

Key "Risk Drivers":

a. 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.

b. 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.

c. 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.

d. Mustard spp.
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.

e. 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.

f. Bluegrass (*Poa annua*)
Bluegrass can become more of a problem under continuous no-till. Though populations do not grow at an explosive rate, control without tillage can be difficult.

g. 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.

h. Legume cover crops

Alfalfa, clovers, and vetches are typically used as cover crops or as part of a forage mix with grasses in conservation plantings that are being converted to cropland. Where forage mixes are present a broad spectrum herbicide, or a tank mix of two herbicides capable of killing both the grass and the legume, will be necessary for control.

i. Field Pansy (*Viola rafinesquii*)

A weed mostly found in the western portion of the corn/soybean belt.

j. Wild lettuce *(Lactuga virosa)*

Common throughout the region but tends to be a problem in no-till or conservation till fields.

k. Red dead nettle (*Lamium purpureum*)

Early flowering plant found more commonly in the southern portion of the corn/soybean belt. Mostly a problem in reduced tillage fields.

Chemical Control:

Photosystem I inhibitor (Triazines): Metribuzin

- Used as a burndown or additive for henbit in Kansas, Missouri and Ohio

EPSP synthase inhibition: Glyphosate

- Highly efficacious and broad spectrum
- Inexpensive
- Low rates
- Timing flexibility
- No carry-over
- No ground water issues
- No residual
- Drift and misapplication are a concern
- Weeds are developing resistance
- Requires special genetics (GMOs) for post emergence application (seed expense)
- Wide price fluctuation
- Soybeans (non-GMO) not eligible for premium price
- Often mixed with 2,4-D
- Temperature dependent efficacy
- Slow to work if using in burndown situation

ALS inhibitors - Pursuit, Scepter, Raptor, Classic

- Crop injury a concern
- Carry-over injury to follow up crop a concern
- Weed resistance is common
- Antagonized by tank mix partners, esp with grasses
- Low to good efficacy on grasses, varies greatly by product
- Low use rates
- Environmentally safe
- Residual effect
- Fall application of Classic & Express esp for Chickweed for seed production suppression and weed control

Other: Gramoxone

- Gramoxone early burn-down
- Typically mixed with 2,4-D to expand spectrum
- Fast acting
- Perception of toxicity
- Weak on horseweed (marestail) and wild lettuce, advanced grasses
- Efficacy is temperature related
- Additive affect therefore usually tank mixed
- Gets some of the difficult weeds
- Better on some weeds than glyphosate
- Cost effective and efficacious
- Timing is critical

"To Do" List
Research

- Researchers should evaluate the life cycle of winter annuals and determine the best time to control, especially henbit, chickweed, mustards, and horseweed (marestail). What insect or disease pests do these weeds harbor or act as host. Evaluate winter annual weeds as secondary hosts and attractants for insects and diseases.
- Producers need to know the best methods of control of chickweed and horseweed (marestail), including spring control of henbit.
- Researchers should also evaluate fall vs. spring control of winter annual weeds.
- Determine a weed control system for corn and soybean to eliminate winter annuals, specifically including residual herbicides.

Education

- Educate producers on weeds as secondary hosts and attractants for insects and diseases.

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 as resistant to herbicides are:
  - waterhemp
  - Palmer amaranth
  - lambsquarters
  - kochia
  - pigweeds
- In addition, in some areas resistant biotypes of the following are found:
  - common ragweed
  - cocklebur
  - shattercane
  - velvetleaf
  - giant foxtail
  - sunflower
  - volunteer corn
  - marestail (horseweed)
  - green and yellow foxtail
  - nightshade (North Dakota)
  - wild oats (North Dakota, Minnesota)

- 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 imadazilinones). There is considerable concern about the potential development of resistance to glyphosate as it also has become widely used within the last 5 years.
- 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 may lose effectiveness 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.
- Principal decision drivers across the region are waterhemp, shattercane, kochia and lambsquarter, and within some areas: Palmer amaranth (Kansas), ragweed (Ohio), nightshade (North Dakota),

Herbicide Resistant Weed Management Approaches:

- 2,4-D is a critical tool to have available to control many herbicide resistant weeds.
- Producers need to use multiple modes of action to control weeds. This is especially true with RR soybeans.
- Management must also consider tillage methods.
- Weed resistance problems have been worsened by farm programs and chemical promotional programs.
- Economics have also played a role in herbicide programs producers use, especially with glyphosate use.
- Weed shifts are occurring with the use of certain herbicides. Producers also need to know what weeds are present and weed size before treating and selecting appropriate herbicide rate.
- Resistant weeds are typically a result of “poor management”, although some seeds from adjacent fields or from blowing pollen may create the problem.

Chemical Control:

Root/shoot inhibitor (Acetamides): Dual, Outlook, Lasso, Harness/Surpass

- For some of the harder to control species the higher rates necessary may not be economical
- With continuous use higher rates have been found necessary for control of some species
- These products work fairly consistently
- Used in herbicide rotations (mode of action)
- No known resistance problems
- Useful in non-GMO systems
- Crop safety good
- No rotational issues
- Provides some residual control

Mitosis inhibitor (Dinitroanilines): Prowl, Treflan

- Economical
- Residual control of annuals
- Has broad spectrum (controls some broadleaf weeds)
- Used in herbicide rotations (mode of action)

- Some crop injury - diseases set in
- Some carryover injury
- Treflan has to be incorporated, doesn't work in no-till systems
- Some resistant weeds but still of minor importance (foxtails, other broadleaf weeds)

Bleaching: Command
- Off-site drift
- Carryover to follow crop
- Expensive relative to some other herbicides
- Erratic control in some situations, need high rates for good efficacy
- Requires shallow incorporation if incorporated for good efficacy
- Least direct crop injury
- Broad range of efficacy when applied properly to annual grasses and broadleaves
- Useful on non-GMO varieties, good alternative to Roundup system

EPSP synthase inhibition: Glyphosate, Glufosinate
- Highly efficacious and broad spectrum
- Inexpensive
- Low rates
- Timing flexibility
- No carry-over
- No ground water issues
- No residual
- Drift and misapplication concern
- Weeds are developing resistance (as yet minor problem)
- Requires special genetics (GMOs) for post emergence application
- Wide price fluctuation
- Seed expense
- Soybeans (non-GMO) not eligible for premium price

ALS inhibitors - Pursuit, Scepter, Raptor, Classic
- Crop injury
- Carry-over injury to follow up crop
- Weed resistance is common
- Antagonized by tank mix partners, esp with grasses
- Low to good efficacy on grasses, varies greatly within mode of action
- Low use rates
- Environmentally safe
- Time of application flexibility
- Residual effect

Aryloxyphenoxypropionates: Assure, Fusilade, Poast, Select
- Effective on volunteer corn, including RR corn
- Difference among products in efficacy
- Difference among products in crop injury
- Weed resistance in foxtail and wild oats - Assure, Fusilade and Poast
- Antagonized by broadleaf control tank mix partners
- Performance diminished under drought conditions

Other: Bentazon, Paraquat (Basagran, Gramoxone)
- Gramoxone early burn-down

- Gramoxone - perception of toxicity

“To Do” List

Education

- Producers, suppliers, and applicators need more education on how to use multiple modes of action to forestall resistance.

IX. Organic soybean production

- Organic soybean production continues to expand.
- Weed control managed through rotation, tillage, hired labor, management practices
- Research is being done by organic producers
- Highly volatile, limited market as of yet
- Providing a consistently quality product is a problem
- Production tends to be either organic or conventional, as producers can’t combine organic and conventional on same farm due to requirements for organic

Future priorities for a reduced-risk pesticide based management system

- Consumers need to be educated about GMOs so producers can use GMOs thereby reducing pesticide use
- Producers need to be educated about the efficient use of pest management practices.
- Producers want the development of a systems approaches to maximize yields while minimizing inputs.

Table 1. Weed Control Ratings based on Herbicide Modes of Action (Families)

	Annual grasses	Perennial grasses and sedges	Annual broadleaf weeds	Perennial broadleaf weeds	Winter Annual Weeds and Cover Crops	Herbicide Resistant Weeds
Photosystem I inhibitor (Triazines): Metribuzin	N	N	YN	N	Y	N
Root/shoot inhibitor (Acetamides): Dual, Outlook, Lasso, Harness/Surpass	Y	N	YN	N	N	Y
Mitosis inhibitor (Dinitroanilines): Prowl, Treflan	Y	N	YN	N	N	Y
Bleaching: Command	Y	N	YN	N	N	Y
EPSP synthase inhibition: Glyphosate	Y	Y	Y	Y	Y	Y
ALS inhibitors - Pursuit, Scepter, Raptor, Classic	Y	YN	Y	YN	Y	N
Protoporphyrinogen oxidase inhibitors: Blazer, Cobra, Reflex, Resource	N	N	Y	N	Y	Y
Aryloxyphenoxypropionates: Assure, Fusilade, Poast, Select	Y	Y	N	N	N	Y
Other: Basagran, Gramoxone	Y	Y	Y	N	Y	Y
Other: 2,4-D	N	N	Y	YN	Y	Y

Y= One or more products within the herbicide group provide adequate control of weeds within the weed category.
N= No product within the herbicide group provides adequate control of weeds within the weed category
YN= One or more products within the herbicide group will provide some control of a limited number of weed species within the weed category.
* Most weeds resistant to herbicides in other families ARE controlled by herbicides from this family.
Note: There is generally some herbicide redundancy for each weed category. The perennial grass weed category has the fewest herbicides that provide adequate control. Some specific weeds within some categories have little or no redundant controls, however, and the loss of some herbicides could significantly affect grower's ability to control those weeds. This is particularly true of weeds such as waterhemp, which developed resistance to several herbicide Modes of Action.

Table 2: Insect Control Ratings of Key Soybean Insects in the North Central Region

SOYBEAN INVERTEBRATE PESTS and INSECTICIDES	Bean Leaf Beetles	Soybean Aphid	Two spotted spider mites	Grasshoppers	Japanese Beetles	Slugs (mollusk)*
Acephate (Orthene)	NL	0	NL	0	NL	NL
Chlorpyrifos (Lorsban 4E)	+++	++++	++++	0	+++	NL
Dimethoate (Cygon)	+++	++++	++++	0	+++	NL
Esfenvalerate (Asana)	0	0	NE	0	0	NL
Methyl parathion (Penncap-M)	0	0	NL	0	0	NL
Phorate (Thimet)	NL	0	NL	NL	NL	NL
Lambda-cyhalothrin. (Warrior)	0	0	0	0	0	NL
Permethrin (Pounce, Ambush)	++++	0	NE	0	++++	NL
Lindane	NL	0	NL	NL	NL	NL
Carbaryl (Sevin)	0	0	NL	NL	0	NL
Methomyl (Lannate)	0	0	NL	NL	0	NL
Thiodicarb (Larvin)	0	0	NL	NL	0	NL
Carbofuran (Furadan)	0	NL	NL	++++	0	NL
BT (Dipel)	NL	NE	NL	NL	NL	NL
Dimilin (Diflubenzuron)	NL	NL	NL	+++	NL	NL
Tillage	NE	NE	NE	+++	NE	++++
Crop Rotation	NE	NE	NE	+++	NE	+++
Biological Controls	0	++++	++++	++++	++++	NE

* Slugs are mollusks; not insects. Molluskcides are being tested for economic control.
++++ = preferred product or primary means of control
+++ = highly effective method of control
0 = effective but not widely used
NL = Not labeled
NE = Not effective

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