

# **Pest Management Strategic Plan For Northern Wheat**

**Hard Red Spring Wheat, Amber Durum Wheat and  
Hard Red Winter Wheat in ND, SD, MN and NE**

**November 20-21, 2003**

**Brookings, South Dakota**

**Sponsored by:**

**USDA North Central Region Pest Management Center**

**Hosted by:**

**South Dakota State University**

**North Dakota State University**

**University of Minnesota**

**University of Nebraska- Lincoln**

## **Project Coordinators, Editors, Projects and Contributing Authors**

### Project Coordinator

And Editor: Brad Ruden, Extension Associate  
South Dakota Project, North Central IPM Center  
241 Ag Hall, Box 2207A  
South Dakota State University  
Brookings SD 57007-1096  
Voice: (605) 688-4596  
Fax: (605) 688-4602  
e-mail: ruden.brad@ces.sdstate.edu

### Cooperating Projects:

North Dakota Project, North Central IPM Center  
Dr. Phillip Glogoza, North Dakota State University

Nebraska Project, North Central IPM Center  
Dr. Shripat Kamble, University of Nebraska- Lincoln

Minnesota Project, North Central IPM Center  
Dr. William Hutchinson, University of Minnesota  
Patrick O'Rourke, University of Minnesota

*Significant portions of this document were excerpted from the Crop  
Profiles developed by the above cooperating projects of the North  
Central IPM Center*

Regional Contacts: North Central IPM Center  
B18 Food Safety and Toxicology Building  
Michigan State University  
East Lansing, MI 48824

Dr. Larry Olsen, Director  
Ms. Lynnae Jess, Assistant Director

### Contributing Authors:

Dr. Marcia McMullen  
Extension Plant Pathologist  
Walster Hall, Room 303  
North Dakota State University  
Fargo, ND  
701-231-7627  
mmcmulle@ndsuxext.nodak.edu

Dr. Yue Jin    Research Plant Pathologist  
USDA/ARS Cereal Disease Laboratory  
1551 Lindig Street  
University of Minnesota  
St. Paul, MN 55108  
(612) 625-5291  
yuejin@umn.edu

Dr. John Watkins  
Plant Pathologist  
448 Plant Science  
Lincoln, NE 68583-0722  
(402) 472-2559  
jwatkins1@unl.edu

Dr. Gary Hein  
Entomologist, Panhandle Research and Extension Center  
4502 Avenue I  
Scottsbluff, NE 69361-4939  
(308) 632-1369  
ghein1@unl.edu

#### Contributing Reviewers

Dr. Marty Draper  
Extension Plant Pathologist  
Plant Science Building 113, Box 2108  
South Dakota State University  
Brookings, SD 57007-1090  
(605) 688-5157  
draper.marty@ces.sdstate.edu

Prof. Leon Wrage  
Extension Weed Scientist  
AgH 229, Box 2207A  
South Dakota State University  
Brookings, SD 57007-1096  
(605) 688-4591  
wrage.leon@ces.sdstate.edu

## **Table of Contents**

Project Coordinators, Editors, Projects and Contributing Authors	ii
Table of Contents	iv
I. Background and Executive Summary	1
II. Northern Wheat: Prioritization of Research, Education and Regulatory Needs	2
III. General Crop Production Practices	5
IV. Hard Red Spring and Durum Wheat Processing	8
V. Worker Exposure to Pesticides	9
VI. Crop Production Timelines	9
VII. Wheat Disease Management- Executive Summaries	12
A. Fusarium Head Blight	12
B. Wheat Rusts	13
C. Leaf Spotting Diseases	14
D. Wheat Curl Mite and Wheat Streak Mosaic Virus	15
E. Russian Wheat Aphid	17
VIII. Wheat Diseases	19
IX. Insect Pests and Control Measures	48
X. Weed Management in Northern Wheat	65
XI. Stored Grain Pests and IPM Strategies	80
XII. Efficacy Tables	86
XIII. PMSP Meeting Attendees	88

## **List of Tables**

Table 1. Production of Wheat in the Northern Great Plains, 2003	8
Table 2. Cultural practices that influence wheat diseases	20
Table 3. Losses due to disease in South Dakota wheat crop, 2003	21
Table 4. Registered seed treatment fungicides and their usage in North Dakota wheat, oats, barley and rye production 2003	40
Table 5. Insecticides Labeled for Use as Empty Bin Treatments in South Dakota, 2004	84
Table 6. Insecticides Labeled for Use as Grain Protectants in South Dakota, 2004	85
Table 7. Efficacy of Insecticides Currently Registered on Stored Grain	86
Table 8. Weed and Crop Response to Herbicides	87

## **Background and Executive Summary**

The US EPA was mandated by the Food Quality Protection Act (FQPA) of 1996 to re-register all pesticides originally registered in the U. S. before 1988. As a result, many important pesticides are undergoing reassessment, including many that are or were used on wheat, such as certain organophosphate and carbamate insecticides, and now some herbicides. To respond to this reassessment process, the Pest Management Center network, including the North Central Pest Management Center (NCPMC) (Now called the North Central IPM Center), has been charged with developing documents to identify and prioritize regulatory, research, and educational needs in pest management for various crops. South Dakota, along with eleven other states in the USDA North Central Region, cooperate as state partners in the North Central Pest Management Center.

The USDA Office of Pest Management Policy cooperates in the development of documents called Pest Management Strategic Plans (PMSPs) with growers, commodity group representatives, land-grant specialists, food processors, crop consultants, agency personnel, and EPA. PMSPs address pest management needs and priorities for individual commodities. Each plan focuses on production of a commodity in a particular state or region. The plans take a pest-by-pest approach to identifying the current management practices (chemical and non-chemical) and those practices under development. Also, priorities are identified for research, regulatory activity, and education/training programs needed for transition to alternative pest management practices for each crop. Currently, 57 PMSPs are completed for a wide range of commodities including fruits, vegetables and field crops (including corn and soybeans) from around the United States.

The goal of the workgroup meeting held in Brookings on Nov 20-21, 2003 was to develop a Pest Management Strategic Plan (PMSP) for Wheat Production in the Northern Great Plains. Because of the many similarities in pest management, hard red spring wheat, durum wheat and the northern belt of hard red winter wheat production (Nebraska northward) were addressed together. Individual regional and state differences in production practices were noted for each crop. Differences across the region following a north to south and/or and east to west gradient were common and will be noted and described in the final document. Nineteen individuals representing growers, consultants, state departments of agriculture, EPA and university personnel were in attendance at the meeting.

Prior to the meeting, attendees received a copy of the preliminary PMSP document as well as an outline of the meeting agenda. Regional experts were solicited to draft summaries of pest management status for current major disease complexes in the region. These documents became parts of the strategic plan document. At the two-day workshop, topics discussed included production and pest management, with a pest-by-pest or pest group discussion of:

- 1) Critical pesticides in wheat production practices
- 2) Critical pest complexes that need further research and those that are the "risk generators" that drive pesticide use
- 3) What are the needs for investment in public research funds, education funds and regulatory activities relative to pest management in wheat
- 4) What factors exist throughout the northern Great Plains that affect pesticide use in these commodities and what is different from other production areas

The final task for the group was to list and prioritize needs for future work in the three areas

of Research, Education/Extension, and Regulatory issues, as described above. The lists of priority issues on the following pages were a result of the discussion from the group.

### General Observations from the PMSP Meeting

During the meeting, it was noted that although the Northern Great Plains Region covered in this Strategic Plan, which includes the states of South Dakota, North Dakota, Minnesota and Nebraska, share relatively similar climates, the pest problems varied significantly from area to area within the region. As noted above, there developed a general north to south and/or east to west gradient in the concern for each pest. As much as possible, this gradient is noted in each pest section.

Other general observations:

- 1) There is a significant concern for the maintenance of phenoxy herbicides (primarily 2, 4-D) as a herbicide option for effective weed management and resistance management.
- 2) Herbicide resistance was a significant concern and needs for research and education into effective resistance management plans and alternatives were brought forward.
- 3) Major pest concerns include winter annual grasses, especially in the winter wheat production areas of Nebraska, Wheat Streak Mosaic Virus, especially in winter wheat, Fusarium Head scab in the wetter areas of the region (east and north) and the associated critical need for full product registration of effective fungicides, and the rust diseases and the associated general lack of genetic resistance to current rust strains in the region. Many other pests were also discussed and are discussed in the specific pest sections.
- 4) There was a strong need identified for development of effective predictive management models for disease forecasting.

## **II. Northern Wheat: Prioritization for Research, Education/Extension, and Regulatory Issues**

### **Top Research Priorities**

1. Improved disease/weed/insect forecasting models. These models need to be based on available weather station data. The system to provide widely available and locally specific weather station data needs to be improved. Where possible, models and available data need to be region wide, not state by state.
2. Increased genetic resistance to emerging rust strains and scab (*Fusarium*) in wheat varieties. This is especially important in durum wheat. Disease resistance in wheats will only widely acceptable if top yield potential and agronomic qualities are maintained.
3. Packaging resistance to diseases as well as resistance to herbicides and insects into the wheat seed.
4. An economically viable solution to winter annual weed problems (IE: jointed goatgrass, downy brome and feral rye) in summer fallow/winter wheat production areas needs to be developed.
5. Consistent economic threshold models for insects and diseases need to be developed or refined. This was especially a priority for the barley yellow dwarf aphid vector.
6. Cultivars under development must maintain or improve competitiveness when compared with agronomic and quality traits of current cultivars.

### Other Research Priorities

1. Problems with volunteer wheat management in future Roundup-Ready wheat production systems need to be addressed. Availability of alternative pesticide products in these systems needs additional investigation.
  - a. Use of all future herbicide tolerant varieties in rotational management systems needs to be investigated further.
2. Production guides with specific recommendations for varieties at locations throughout the region need to be developed. Examples include: trials on varying soil types, textures, pH, micronutrients, environmental factors, disease and insect resistance, etc. that affect specific varieties.
3. Improved drought tolerance and resistance in new cultivars.
4. Better fungicides for scab (*Fusarium*) control in all wheat production systems.
5. Documentation of protein changes, quality changes, etc, that will possibly be present in a future Roundup-Ready wheat or other biotech-based wheat production system.
6. There is a need for improved understanding and management of the wheat curl mite and its role in wheat streak mosaic management across the entire region.
7. The future potential and impact of a known new biotype of the Russian wheat aphid that is coming into the region from the southwest needs to be documented.
8. A “systems” management approach with respect to rotations (with biotech and without biotech varieties), Farm Bill requirements, cultivar selection, etc. needs to be investigated.

### Top Education/Extension Priorities

1. Education on improved disease/weed/insect forecasting models. These models need to be based on available weather station data, and the system to provide widely available and locally specific weather station data needs to be improved. Where possible, models and available data need to be region wide, not state by state.
2. Education on the use of production guides that contain specific recommendations for varieties at locations throughout the region need to be developed. Examples include: trials on varying soil types, textures, pH, micronutrients, environmental factors, disease and insect resistance, etc. that affect specific varieties. Include insecticides, herbicides, fungicides, and fertility and fertilizer management in the educational programs.
3. Increased education on rotation of pesticides and pesticide modes of action for management of current resistance and avoidance of future resistant pest populations.
4. It is very important to keep web sites up to date with information on current situations and conditions. Web sites and other electronic delivery methods for pest alerts, etc. are critical to effective and timely pest management.
5. There is a need for greater distribution of information to alert growers of the potential for risk of sporadic pests to occur. Wide distribution and education on the use of monitoring, prediction and modeling data is needed.

### Other Education/Extension Priorities

1. Community education on pesticide and nutrient management issues is needed. Current efforts focus primarily at the producer level, not the community level.
2. Increased education on tank mixing issues, including compatibility, antagonism, etc. of potential tank-mix partners is needed.
3. Increased education and awareness of worker safety issues – including insecticide, herbicide, and fungicide use are concerns. These issues are important for handler, mixer/loader, applicators and field workers/scouts/consultants.
4. Education on direct seeding and minimum tillage and their role and fit into production systems is needed.

### Top Regulatory Priorities

1. The registration for 2, 4-D needs to be maintained for use on wheat **for the entire region**. Continued availability of 2, 4-D products is critical for effective weed control and resistance management.
2. Regional coordination of timely Section 18's and 24 (c) requests is a priority. Regional coordination of these requests has the potential to reduce redundant workload, increase availability of products and increase timeliness of these requests.
3. Use crop groupings for pesticide registrations whenever possible to get products available for all types of wheat. The IR-4 program uses crop groupings in the research conducted on pesticides. Following this model would potentially allow for wider availability of certain pesticides.
4. Full federal use labels (Section 3 labels) for newer triazole fungicides, such as Folicur, are needed for scab (*Fusarium*) management. Current availability of certain products is only through special labels (Section 18 and Section 24 (c) labels), which are in force only for short time periods and must be continually renewed.
5. Market segregation of grain is a current and future issue. There is a need for guidelines and uniformity (harmonization) of testing procedures and standards for quality, dockage, etc.
6. There is a need to maintain pesticide options for a crop, such as wheat, where use is sporadic but occasional significant needs arise. Overall, when needed, pesticide options must be available.

### Other Regulatory Priorities

1. There is a need for the federal Risk Management Agency to reevaluate rules for crop insurance. An example of the need is for the timely investigation and approval that is needed for crop destruction if a disease such as wheat streak mosaic in young wheat fields becomes a critical issue in certain areas.
2. There is a need to maintain atrazine for use in rotational programs for wheat. Atrazine is not used directly on wheat but is used for control of volunteer wheat in certain production systems in the region. Regionally, this use is mostly limited to the wheat-fallow production systems where it is not in a corn rotation, is used at low levels and is used in



areas where water issues are not an concern because aquifers are very deep (as much as down 300 feet). This production system was described in southwestern Nebraska, but may be used in other areas of similar climate (western and southwestern areas) within the region.

### **III. General Crop Production Practices**

*The following are excerpted from crop profiles completed by the Pest Management Center Programs in the four state region covered by this Strategic Plan.*

#### **South Dakota**

Wheat is sown in South Dakota as a spring crop, primarily in late March, if possible, and April. Production is severely inhibited if planting continues into May, with production generally declining up to one bushel per acre per day if planting takes place after May 10. Wheat is a flexible crop that fits well into various tillage and management schemes. Wheat may be direct seeded into tilled soil, under reduced tillage schemes and as a no-till crop. No single tillage practice is significantly better than others, and under proper conditions they all will work satisfactorily. No matter what tillage system is used, a good seed bed is required, with seed placed in moist soil as shallow as possible and the moist soil firmed around the seed. These conditions result in the most rapid germination. Seeding rate is targeted at 28 seeds/square foot. For average seed, this is 1.2-1.5 bushels per acre. A common production practice is to include wheat in a three-year rotation of corn, soybeans and wheat in the eastern part of the state. Wheat does not respond well to continuous cropping, as increased pressures from *Fusarium* head blight (scab) and leaf spotting diseases as well as possible increased insect pressure make continuous production prohibitive. *Fusarium* head blight can also be a significant problem in fields planted into corn stubble, as the *Fusarium* fungus is present in the decaying corn residue. Therefore, the usual practice is to place the wheat crop following the soybeans in a three-year rotation or following fallow or a non small grain in other production systems.

No-till production increases the amount of crop residue on the surface of the soil. This residue cover decreases water runoff and may increase soil organic matter over time. However, the residue may keep the soil from warming in the spring and may delay rapid germination of the wheat seed as a result. Additionally, no-till crop production reduces water loss caused by tillage. Normally, this reduced water loss would be advantageous to the crop in increased water supply. Recent extremely wet weather patterns, especially in the spring months, have caused no-till planting of spring wheat to be delayed as compared with that under conventional tillage. No-till has, however, been a very successful production practice in much of South Dakota.

#### **North Dakota**

North Dakota has a temperate climate that is conducive to growing wheat. Average annual days above freezing range from 110 days in the North to 130 days in the South. Average growing season precipitation ranges from 16.0 inches in the Southeast to less than 12.0 inches in the Northwest. North Dakota soil types range from rich organic soils in the east to lighter soils in the west. This combination of climate and soils is ideal for statewide wheat production.

Spring and durum wheats are planted in the spring, from late April to the end of May. Seedbed preparation can vary based on the type of seeding equipment used. No-till, and reduced

tillage drills are designed for use in high residue conditions. Conventional drills require greater seedbed preparation. This is achieved through the use of tillage equipment in the fall following harvest and in the spring prior to seeding. Row spacing ranges from 6 to 9 inches with seed planted at 2 inch depth or less. A plant population of 28 to 30 plants per square foot is desired. Spring and durum wheats are harvested in the fall from early August to late September. During the 1990's, durum yields averaged from 22 to 38 bushels per acre, while spring wheat yields range from 25 to 42 bushels per acre.

## **Nebraska**

Hard red winter wheat is produced throughout Nebraska; however, 75% of the wheat production is in the western half of the state, with approximately 45% grown in the Panhandle. Approximately 92% of the winter wheat acreage is in dryland production. Because most of the wheat is grown in an arid region (ca. 14-21 inches annual rainfall), water availability is the limiting factor in wheat production in western Nebraska.

In 1999, Nebraska ranked 6th in the United States in winter wheat production. Wheat acreage runs around 2 million acres with 1.8 million harvested in 1999. Record wheat yields were seen in 1999 at 48 bushels per acre. Total production for 1999 was 86.4 million bushels. Few acres of spring wheat are produced in Nebraska because it matures later in the summer than winter wheat resulting in reduced yields due to heat stress. Some Nebraska growers are beginning to grow hard white winter wheat, but current acreage is less than 10,000 acres. This is projected to increase in the future, but will be limited by the handling and identity preservation capabilities of the marketing system.

Winter wheat production is characterized by very narrow profits margins. Limited per acre profits result in growers needing to farm large acreage to make sufficient profits, and this limits the grower's ability to manage pests. Another complicating factor in wheat production in Nebraska is the risk of drought or hail. The western part of the state being arid is prone to dry periods, but a good portion of western Nebraska is also in an area of highest risk for hail in the United States. These factors make wheat growers in Nebraska very conservative in their management of the wheat crop and in management of the pests of wheat.

Much of the wheat in western Nebraska has historically been grown in a wheat-fallow rotation with the fallow period used to increase water storage in the soil. Over the last two decades there has been an increase in rotations with an additional crop being grown. This crop has included corn, sorghum, millet, or sunflowers. The inclusion of these crops in the rotation has in some cases displaced fallow but most often has been in addition to the wheat-fallow. Because of the need to conserve all available water, the move to increased diversity in the crop rotation has occurred in conjunction with an increase in no-till or minimum till practices. This shift to more intensive rotations and reduced tillage practices has been most prevalent in the wheat growing areas of western Nebraska with the highest rainfall (i.e. southwest, 17-21 inches annual rainfall). Movement to a more diverse rotation has been slower in the Panhandle where moisture is more limiting. However, recent changes in the farm bill have resulted in an increase in the Panhandle in more diverse rotations with growers including more corn, sunflower, millet or other crops in their rotation with wheat and fallow. These rotation considerations, along with the Conservation Reserve Program (CRP), have resulted in reducing wheat acreage in Nebraska over the past two decades.

Winter wheat planting begins in the west in late August at the higher elevations and proceeds to the east with the latest planting occurring in the east. Harvesting of the previous

crop may delay planting in irrigated fields into late September or early October. Moisture availability for seed germination and plant emergence is the greatest concern for growers in the fall, and often growers will risk increased insect or disease problems to plant early when soil moisture is optimum. Reduced growth of the wheat in the fall leaves fields prone to wind erosion through the winter because of the reduced precipitation that occurs through this time. Winter wheat in Nebraska will break dormancy in March, and spring moisture will be critical to developing yield potential. Harvest of wheat in Nebraska begins in the east in late June or early July and continues to the west with harvest in the highest elevations in the west (Panhandle) occurring in mid to late July. During the summer, weed management in fallow fields is critical to maintaining available soil moisture for wheat to be planted in the fall.

Growers rely heavily on the yield and other characteristics associated with the varieties that they plant. Their first consideration in variety selection is potential yield and seed quality. Wheat maturity and winter hardiness are extremely important factors in a varieties' ability to produce consistent yields in Nebraska. Plant height and straw strength are important factors in maintaining adequate surface residue while preventing lodging. Coleoptile length is important because seeds with longer coleoptile length will emerge better when being planted deep to reach moisture under dry planting conditions. Insect and disease resistant varieties are very important management tools because they may reduce costly management practices (e.g. pesticide applications).

### **Minnesota**

Minnesota spring wheat is seeded in late April-early May and harvested in August. Plant populations of 1.2 million plants/acre are recommended. Planting equipment has been rapidly changing from press wheel drills to air-seed systems that perform tillage, seeding and fertilizing operations in a single pass. Improvements in equipment mean the entire wheat crop can be seeded over a three-week period with favorable weather conditions.

Wheat is commonly grown in three or four year rotations with other crops. Crop rotation is an important cultural control practice in an IPM program for disease management, insect suppression, and weed management. Rotating crops keeps *Fusarium* head blight, tan spot, and common root rot in check as well as insect pests such as Hessian fly and orange wheat blossom midge. In addition, the practice of rotating crops aids in the management of difficult and expensive to control weeds such as wild oat. Use of tillage to manage pest problems has limited the use of no-till systems in Minnesota wheat production. Many wheat producing areas of the state are prone to soil erosion losses from wind and/or water, but tillage aids in the suppression of pests such as *Fusarium* head blight, Hessian fly, and weeds including foxtails. Wheat producers should try to leave crop residue on the soil surface to reduce erosion but selectively increase the amount of tillage on fields based on pest pressure.

**Table 1. Production of Wheat in the Northern Great Plains, 2003**

<b>All Wheat</b>				<b>Winter Wheat</b>			
State	Production X1000 bu	% of Total US	State Rank	State	Production X1000 bu	% of Total US	State Rank
ND	317090	13.57%	2	NE	83720	4.90%	5
SD	116241	4.97%	6	SD	59340	3.48%	9
MN	105482	4.51%	7	ND	5880	0.34%	27
NE	83720	3.58%	10	MN	966	0.06%	38
Total	622533	26.64%		Total	149906	8.78%	

<b>Other Spring Wheat</b>				<b>Durum Wheat</b>			
State	Production X1000 bu	% of Total US	State Rank	State	Production X1000 bu	% of Total US	State Rank
ND	252800	47.45%	1	ND	58410	60.44%	1
MN	104400	19.59%	2	SD	621	0.64%	5
SD	56280	10.56%	4	MN	116	0.12%	6
Total	413480	77.60%		Total	59147	61.21%	

**IV. Hard Red Spring and Durum Wheat Processing**

Hard red spring has the highest protein content of all U. S. wheats, usually 13 to 16 percent. High protein content corresponds with greater gluten content. For this reason, flour mills in the United States and in many export markets blend hard red spring wheat with lower protein wheats to increase the gluten content in flour. The addition of hard red spring improves dough handling and mixing characteristics, and water absorption.

Durum is the hardest of all wheats. Its density, combined with its high protein content and gluten strength, make durum the wheat of choice for producing premium pasta products. Pasta made from durum is firm with consistent cooking quality. Durum kernels are amber-colored and larger than those of other wheat classes. Also unique to durum is its yellow endosperm, which gives pasta its golden hue.

When durum is milled, the endosperm is ground into a granular product called semolina. A mixture of water and semolina forms a stiff dough. Pasta dough is then forced through dies, or metal discs with holes, to create hundreds of different shapes.

Durum production is geographically concentrated in North Dakota and the surrounding area because it demands a special agronomic environment. North Dakota produces 73 percent of the U.S. durum crop. South Dakota and Minnesota have small durum production areas, accounting for 600,000 bushels and 100,000 bushels, respectively, in 2001 compared to North Dakotas' 54.6 million bushels of production. Many international and domestic millers prefer North Dakota durum for its color and strong gluten characteristics.

## **V. Worker Exposure to Pesticides**

Worker exposure to pesticides in wheat production is, in general, expected to be significantly lower than for production of other crops. Reasons for lower worker exposure include:

- 1) Plant growth habit. Wheat is a spring or winter annual grassy field crop which reaches a mature height of no greater than four feet. Although exposure can occur from crop scouting, this exposure is limited by infrequent scouting activities.
- 2) Hand labor in wheat production fields is nearly non-existent.
- 3) Pesticide application occurs at specific times through out the production season. These pesticide applications are generally well-spaced from each other in time.
- 4) In general, for the pests that are driving pesticide application in wheat production, including weeds and plant diseases, immediate scouting of the fields after pesticide application is not needed or practiced. Control of these pests cannot be observed for several days to weeks after pesticide application. Primary scouting for pests is prior to pesticide application.

Worker exposure to pesticides in wheat production is limited primarily to mixer/loaders and handlers of the concentrated pesticide products prior to application. Pesticide application in wheat is completed by ground and aerial pesticide application. Timing of potential pesticide applications is noted in the timelines below. It must be noted that rarely are pesticides applied at all of the possible application times. With the exception of a primary herbicide application, which is used on 95% or more of planted acres, nearly all other pesticide applications are dependent on environmental conditions present throughout the year.

Potential worker exposure times include:

- 1) Pre-planting burndown herbicides
- 2) At-planting seed treatment fungicides. Insecticides may also be used as seed treatments, although this use is not as common.
- 3) In general, the primary herbicide application is at the 3-5 leaf vegetative growth stage. Early fungicide application may occur at the same time.
- 4) Fungicide application at flag leaf stage (late vegetative growth).
- 5) Fungicide application at heading for scab control.
- 6) Pre-harvest herbicide use.
- 7) Post-harvest burndown of volunteer grain and perennial weeds.

## **VI. Crop Production Timelines**

Wheat production in the Northern Great Plains includes production of both spring-seeded and fall-seeded (winter) wheats. Hard red spring and amber durum wheat are spring-seeded wheats. Hard red spring wheat is grown in the northern and eastern areas of the region, with very little being grown in the southern and southwestern areas of the region. Amber durum wheat is primarily grown in North Dakota, with lesser production area in northern South Dakota and northwestern Minnesota. Hard Red winter wheat production is centered in central and western Nebraska and central and western South Dakota, with much lower production in other areas of the region. The following pages show general timelines for production of spring-seeded and fall-seeded wheats.

## Timeline- Spring Cereals in South Dakota

Management Activity	Day	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Lat	
		1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	15	Fall
Educational programs for producers																							
Soil sample, if not done in fall																							
Preplant fertilizer, if not done in fall																							
Scout- army cutworm																							
Seeding (Suggested before May 15-24)																							
Burndown herbicide (if used)*																							
Germination																							
Scout- armyworm and Russian wheat aphid																							
Post-emergence herbicide**																							
Tillering																							
Late vegetative growth- possible fungicide***																							
Top dress N fertilizer, if not earlier																							
Scout- aphids																							
Jointing																							
Scout- tan spot, if early rains																							
Scout- stem maggot and sawfly																							
Scout- grasshoppers																							
Boot stage																							
Scout- rust diseases																							
Flowering																							
Scout- scab (fungicide if wet forecast)																							
Milk stage																							
Hard dough stage																							
Preharvest herbicide (weed desiccation)#																							
Ripening/Harvest																							
Post-harvest tillage of herbicide (annual weeds)																							
Herbicide for perennial weeds																							
Fall tillage for perennial weeds and soil sampling																							
Fall fertilizer																							
Scout- late fall weeds (cheatgrass, quackgrass)																							

Notes: \* Burndown herbicide for winter annual and early emerging spring annual weeds  
 \*\* Post -emerge herbicide for spring annual broadleaves and grasses  
 \*\*\* Late vegetative fungicide to protect flag leaf only if disease eminent and wet forecast  
 # Pre-harvest herbicide usually applied 7-10 day prior to harvest



## **VII. Wheat Diseases: Executive Summaries**

### **A. *Fusarium* head blight.** Marcia McMullen, NDSU

*Fusarium* head blight (FHB) epidemics in the U. S. have caused enormous yield and quality losses of wheat in the northern Great Plains. In 1993, over \$1 billion was lost to ND, MN and SD producers due to reduced yields and quality from FHB. Other epidemics occurred in these three states in 1994, 1997, and 2001, and scattered outbreaks occurred in the region other years, including in Nebraska and eastern Montana. All classes of wheat are vulnerable. Frequent rainfalls and long durations of high relative humidity during flowering and grain fill favor infection by the causal fungus. Prolonged wet weather also favors formation of deoxynivalenol (DON), a toxic byproduct of this disease. The disease survives in infested grain straw, chaff, and seed.

Control of this disease has been difficult, because of the complex nature of the host/pathogen interaction. Host resistance is a promising and effective management solution, but resistance has not been easy to achieve in adapted cultivars. In the meantime, farmers have needed some *immediate solutions* for keeping this disease from causing severe economic loss. Included in these immediate solutions is the planting of the most tolerant cultivars available, use of crop rotation practices that limit disease carryover in wheat residue, use of seed treatments to reduce risk of seedling blight, and use of fungicides to reduce FHB disease levels.

Research efforts in each state address development of resistant cultivars, screening of germplasm, development of marker-assisted selection, transformation, understanding the epidemiology of the disease, understanding food safety and toxicology, and evaluation of fungicides and biological agents for disease control. Research is funded through various sources, including the USDA/ARS and the U.S. Wheat and Barley Scab Initiative, state initiatives, commodity organizational support, and private industry.

Tests of fungicides across wheat classes and environments allow evaluation of the consistency of a product's performance over different environmental conditions and grain classes. In 1998, a Uniform Fungicide Trial conducted across seven states provided data on efficacy of five products or product mixes in reducing FHB when applied at heading. Across the test sites, an average of about 50% reduction in FHB occurred, as well as a 30-40% reduction in DON occurred for most, but not all, products. Additional work across multiple states continues - to find more efficacious products that reduce disease severity as well as DON levels, and that are economical and safe to the environment and the applicator. Currently, a 24(C) registration in some states allows use of Tilt (propiconazole) for heading application to wheat, while a Sec. 18 Emergency exemption for Folicur (tebuconazole) allows similar application to wheat for FHB control. More efficacious, experimental products are also being tested, and generally compared to Folicur in efficacy.



## **B. Wheat Rusts.** Yue Jin, University of Minnesota

Stem rust (caused by *Puccinia graminis* f. sp. *tritici*), leaf rust (caused by *P. triticina*), and stripe rust (caused by *P. striiformis*) are some of the most widely recognized diseases in wheat. Stem rust and leaf rust occur almost wherever wheat is grown, whereas stripe rust is generally restricted to areas where temperature in the growing season is cool. Historically, stem rust was one of the most destructive diseases in the North Central region. However, a severe stem rust epidemic on wheat has not occurred in this region for nearly 50 years due to the use of resistant varieties and eradication of the alternate host, common barberries (*Berberis vulgaris*). The disease remains to be a threat to wheat. Leaf rust has been one of the most persistent problems in wheat production in the region. In recent years, many leading hard red spring wheat varieties have become susceptible to leaf rust in the northern Great Plains where leaf rust resistance was stable and adequate for many years in the past. This has led to the increased use of fungicides in wheat. Stripe rust, traditionally a disease of importance in the Pacific Northwest, has become a significant problem in southern US and the Great Plains in recent years. In the past five years, measurable yield losses to stripe rust have occurred in several localities in the North Central region. It remains to be seen whether stripe rust will become established as a major disease of wheat in the region.

Wheat rusts are managed primarily by the use of resistant varieties. Stable resistance to stem rust has been achieved in all classes of wheat by pyramiding several highly effective resistance genes into a single variety. Occasionally, varieties with inadequate levels of stem rust resistance were used in commercial production, resulting in localized stem rust epidemics and yield losses. Efforts to maintain adequate stem rust resistance are being made in nearly all germplasm improvement and varietal development programs in collaborations with USDA-ARS. In contrast, stable resistance to leaf rust has been difficult to achieve. A new variety, resistant to leaf rust when first released, often becomes susceptible within a few years of cultivation due to the selection of races that possess virulence toward the resistance being used. Varietal improvement for leaf rust resistance remains to be one of the major objectives in many varietal development programs.

Current research focuses on population genetics of rust pathogens, host-pathogen interactions, and identification and utilization of resistance genes or gene combinations that impart durable resistance. The annual nation-wide survey of virulence compositions of cereal rusts conducted by USDA-ARS research facilities in conjunction with evaluations of critical breeding germplasm provide vital information on race dynamics in the rust populations and establish the knowledge basis for developing stable resistance. Recent research trends in genomics of rust pathogens as well as of wheat will likely result in a better understanding of the host-pathogen interactions and development of strategies of better disease management.

**C. Leaf Spotting Diseases: Tan Spot, Septoria Leaf & Glume Blotch in the Hard Red and Hard White Winter Wheat Belt of the Northern Great Plains.** John E. Watkins, University of Nebraska-Lincoln

Tan spot and the Septoria diseases thrive in agro ecosystems that maintain large amounts of wheat residue for erosion control purposes. In the hard red and hard white winter wheat belt of the northern Great Plains, moisture availability often limits successful wheat production. In the western regions of Nebraska, South Dakota and North Dakota, hard red and hard white winter wheat production revolves around a 14 month wheat-fallow-wheat system, primarily to conserve soil moisture. Many producers plant alternate strips every other year, leaving standing wheat stubble in those strips not cropped. It is on this residue that the fungi causing tan spot and the *Septoria* diseases survive.

In most situations and during most years, tan spot predominates as the primary leaf spotting disease, but in some years the *Septoria* disease can be quite evident. Years with frequent rain in May and June, which favors crop production, also favors tan spot. Moisture stimulates abundant fungal spore production in the specialized fungal structures on the wheat residue, and wind moves these spores to growing wheat in adjacent strips. The rain also provides the moisture needed for the spores to germinate and infect. Once established on the growing wheat, secondary spore production on leaf lesions enhances spread of the disease in a wheat field. In a wetter year infection of the upper canopy may become severe enough to affect yields. However, in most years, June's hot, dry windy conditions retard tan spot and *Septoria* disease development and the environment become the yield limiting factor, not the disease.

A significant upturn in interest in more intensively managed wheat grown under center pivot irrigation, has resulted in a greater concern over foliar diseases i.e. rusts, leaf spots and powdery mildew. The dense heavily fertilized canopy and the overhead irrigation provide ideal conditions for foliar disease development. Although all can be affectively managed through foliar fungicide application, this method is costly in a market where growers are trying to reduce input costs. An alternative to fungicide application is variety selection. The reaction of wheat varieties to the rusts is well known; however, information on the reaction to tan spot and the *Septoria* diseases for the northern Great Plains is lacking. Hard red and hard white winter wheat varieties should routinely be screened for reaction, not only to the rusts but to the leaf spots and powdery mildew as well, and this information made available to producers. Wheat breeders could use this information to pyramid genes for multiple disease resistance in their breeding programs. Providing producers with adapted high yielding and good quality wheat with moderate to good levels of resistance to the rusts, leaf spots and powdery mildew enhances sustainability of the wheat production through greater adoption of conservation tillage along with greater producing returns to the grower.

#### **D. Wheat Curl Mite / Wheat Streak Mosaic Virus.** Gary L. Hein, Univ. of Nebraska

The wheat curl mite, *Aceria tosichella* Keifer, transmits two serious viruses, wheat streak mosaic virus (WSMV) and high plains virus (HPV), to wheat (*Triticum aestivum* L.) throughout the Great Plains. Wheat streak mosaic has long been considered the most serious disease of winter wheat in the western Great Plains. High plains virus (HPV) was identified from wheat and corn throughout the Great Plains in the mid-1990's. Because the wheat curl mite transmits both of these viruses, both viruses are often found together in mixed populations in the field. The extent of the interaction of the two viruses is not known; however, it is clear that where one or both of viruses are present, the resulting disease complex significantly impacts wheat.

Widespread wheat streak mosaic epiphytotics have occurred sporadically since the 1950's when the virus was first detected. However, in most years the disease is limited to individual fields or groups of fields. It is not uncommon for severe infestations to result in a 100% loss. In western Nebraska, we have seen three serious epiphytotics in the last ten years. In Kansas where a formal disease loss survey is conducted each year, they estimate an average annual loss of about 2% to wheat streak mosaic virus with high and low loss estimates of 13% (52,000,000 bu) and 0%, respectively (Appel et al. 1996). These loss estimates may be most indicative of the losses from this disease complex across the central Great Plains (Nebraska, Kansas, Colorado), but significant losses also occur across the entire Great Plains from Canada and North Dakota south to Texas. In 1988, North Dakota suffered an estimated \$40 million loss from wheat streak (McMullen and Nelson, 1989).

As with most arthropod-vectored diseases, management of WSMV relies on managing the vector. The most prevalent problems with this disease complex arise when hail shells seeds out of the headed wheat, producing volunteer wheat before harvest. Mites quickly infest the volunteer wheat and build up large populations along with increasing the virus titer in the volunteer wheat. Thus, volunteer wheat serves as a "green bridge" to carry both the mite and viruses to the newly emerging winter wheat in the fall. Cultural practices are targeted at eliminating volunteer wheat, and thus reducing the potential for fall infections. Often, environmental conditions make volunteer wheat control problematic, and the disease potential persists. In addition to volunteer wheat, corn, foxtail, millet, and a number of grasses serve as alternate "green bridge" hosts for the mites and viruses. The contribution of these alternate hosts to disease risk is considered to be much less than the pre-harvest hail risks, but significant nonetheless.

The significant impact and persistence of this disease problem in Great Plains winter wheat has resulted in considerable effort being put into the development of wheat varieties that are resistant to wheat curl mite and/or WSMV. A good deal of work has been done through the last 25 years to identify sources of resistance to wheat curl mite and develop resistant wheat varieties. One of the first wheat curl mite resistance genes originating from a translocation of rye into wheat was deployed in the variety 'TAM 107'. TAM 107 and some other varieties with the same gene were planted widely in the central Great Plains, but through the last 10 years the wheat curl mite populations in the region have overcome this resistance gene. Several additional sources of resistance to mite colonization have been identified from wheat relatives and transferred into wheat, but as yet, none of these genes have been widely deployed. A major drawback to

widespread deployment of most of these genes is that the reaction to these genes is varied depending on the source of mites that are used. Differences between mite populations in response to resistance genes have been found, and this has serious implications to gene deployment and managing these genes to avoid resistance. In recent years, promising genes have also been located and transferred to wheat from wheat relatives that have very high levels of wheat streak mosaic virus resistance. These advances have tremendous potential for improving our ability to manage this disease.

### **Research Needs to Improve Future Management of Wheat Streak Mosaic**

- ▶ Increased understanding of mite ecology and virus epidemiology
  - mite movement directly results in virus spread
  - environmental influence on virus buildup
  - improved ability to predict infestations/infection potential
- ▶ Determine the effects transgenic (Roundup Ready) wheat may have on epidemiology
- ▶ Influence of rotational crops on over summering ability of mites
  - corn, forage grasses, volunteers within alternate crops
- ▶ Development of resistant varieties to wheat streak and/or wheat curl mite
  - biotype complications on utility of mite resistant varieties
  - ability of virus to adapt or become resistant to varietal resistance
- ▶ Improved understanding of the transmission process
  - understanding regulating factors may help target resistance strategies

### **References:**

- Appel, J. A., R. L. Bowden, W. W. Bockus, and M. G. Eversmeyer. 1996. Preliminary 1996 Kansas wheat disease loss estimates. *In: Kansas Cooperative Plant Disease Survey Report, August 29. Kansas Department of Agriculture, Topeka, KS.*
- McMullen, M. P. and D. R. Nelson. 1989. Wheat streak mosaic severe in 1988. *N. D. Farm Research. N. D. Ag Exp. Station, Fargo, ND, p. 14-16.*

## **E. Russian Wheat Aphid.** Gary L. Hein, Univ. of Nebraska

After it was first found in the U.S, in 1986, the Russian wheat aphid quickly spread from Texas north and west into all 17 states west of the 100<sup>th</sup> Meridian and into Canada within the next two years. The aphid did not spread significantly to the east and was limited to western parts of Nebraska and North and South Dakota. However, severe infestations during the 1989-90 season resulted in losses of \$5.2 million in western Nebraska alone. The severity of this insect during the first years of its presence quickly made it the most important cereal insect pest in the region. Damage from the aphid was extensive with losses in individual fields approaching 100% in some areas. Control of the aphid could be obtained with chemical treatment but at a significant cost in a system with a very narrow profit margin. Management of the aphid relied on cultural tactics of volunteer control, delayed planting date and scouting for economic infestations. By the mid 90's varieties with resistance to the aphid were present in Colorado and to a lesser extent in surrounding states. Increased use of the resistant varieties in Colorado decreased the economic impact of the insect in the severely impacted areas.

After several years of severe infestations in numerous states, particularly centered on Colorado and its neighboring states, the severity of the insect waned. Colorado continued to have the most severe problems but infestations in surrounding states became limited to more localized and less severe infestations. The Russian wheat aphid is an arid climate insect, but its presence in the ecosystem relies on its dependence on alternate hosts to carry it through the summer. An extremely dry summer does not allow it to do well on the alternate grasses found in the region. In addition, very cold winters severely impact its survival. The lack of movement of the aphid eastward is attributed to the higher humidity found in these areas and the interaction of humidity and disease. Wet conditions during the spring and early summer also severely inhibit the aphid in the region. Optimum conditions for the aphid would be moderate moisture in the summer for its alternate hosts to do well, a warm extended fall, a mild winter, and a relatively dry and warm spring and early summer. As can be seen, the influence of environmental conditions on the insect are significant and in many years extremely limiting. Another factor that may be acting to reduce aphid presence and severity is the action of natural enemies. Predators, especially lady beetles, and a number of parasitic wasps have been found to be very numerous at times on aphid populations. It is unclear as to the actual impact of these natural enemies on Russian wheat aphid dynamics.

In 2003, observations in southeast Colorado indicated that a new biotype of Russian wheat aphid was probably present because it was surviving and severely damaging resistant varieties across a wide area. Later in the spring of 2003 this aphid had appeared in western Nebraska and was damaging resistant wheat varieties. The impact of this new biotype is not known but early indications are that it actually is more damaging on susceptible varieties than the original aphid type. Also, the biotype appears to be resistant to a number of resistance genes that have been identified. This new biotype creates a significant amount of uncertainty in what the future pest status of this insect throughout the Great Plains will be over the next years.

## **Research Needs to Improve Future Management of Russian Wheat Aphid**

- ▶ Determine the impact of the new resistant biotype
  - survey to determine spread and potential for increased problems
  - verify impacts on newer varieties
- ▶ Identify additional resistant sources and develop varieties with new resistance
- ▶ Determine the true impacts that natural enemies have on ecology of the aphid
  - determine both regional and local impacts
  - determine interactions natural enemies have with rotational crops
- ▶ Develop and introduce varietal resistance for alternate crops affected by the aphid, i.e. barley

## **VIII. Wheat Diseases**

Many diseases have a significant impact on wheat production in the Northern Great Plains. Losses vary from year to year, but some diseases, in epidemic years can be catastrophic. Cool moist soil in the spring slows the growth of wheat and promotes the growth of diseases. Prolonged exposure to dry soils can also hinder germination and promote diseases. Foliar diseases can also be a serious problem in Northern Great Plains. Disease causing fungi can survive in crop debris, field trash, and sometimes seeds. Usually a prolonged period of high moisture and humidity is required for disease organisms to infect growing wheat fields.

During the 1990's, epidemics of Fusarium head blight reduced on-farm income by millions of dollars in the spring wheat growing areas. The most severe epidemic was in 1993, but the 1999 epidemic was also quite severe. Spring wheat losses to scab in South Dakota were 5,800,000 bu in wheat alone, with an estimated loss in value of \$17,800,000. Losses were much higher in North Dakota.

In western Nebraska winter wheat, the most serious diseases are wheat streak mosaic, which is transmitted by the wheat curl mite, and root and crown rot. In eastern Nebraska, soil-borne mosaic and leaf rust are the primary disease problems. Additional diseases, including barley yellow dwarf, smut diseases, *Septoria* leaf and head diseases, *Fusarium* head blight (scab), *Cephalosporium* stripe and tan spot can also become important on a localized scale.

### **Disease Management**

#### **Non-Chemical Control**

- Wheat diseases are best managed with a combination of cultural and chemical controls.
- Rotating other crops with wheat and burying crop residue are examples of cultural controls.
- Due to the relatively low profit margins in dryland winter wheat and other wheat production and the sporadic nature of the diseases, most disease management practices are cultural practices that require limited input costs.
- The health of a wheat crop is the result of management factors related to varieties, seed quality, seedbed, planting date, residue management and weed control.
- Using adapted varieties that are resistant to major diseases is an important management tactic. Varietal resistance or tolerance is important in leaf rust and soil borne mosaic in eastern Nebraska and for wheat streak mosaic in western Nebraska.
- Several diseases can be associated with poor seed quality or bin run seed. Using certified, disease-free seed is an important management tool for these seed associated diseases. Additional control of these diseases can be obtained from fungicide treatments to the seed, but the additional cost of this practice limits its use.
- Seedbed quality is an important component of disease management. In addition to insuring a rapid germination and emergence of the wheat plant, the health and vigor of the wheat seedling will influence its susceptibility to disease. Root and crown rot is a disease complex caused by the interaction of infection of roots and crowns by fungi, harsh winter conditions, early planting and loose seedbeds. A loose seedbed and prolonged moisture stress coupled with relatively high soil temperatures in the fall enhance early disease development in the root and crown.
- Reducing stress on the plants by planting at the optimal date into a firm and moist seedbed

will lower the risk from the root and crown rot disease complex. Planting too early will increase the risk of wheat streak mosaic and barley yellow dwarf as it will allow for earlier vector buildup in the wheat. This will also increase the likelihood of drought stress on the plants, which will increase the risk of root and crown rots.

- Some diseases are affected by crop rotation and plant residue management. *Cephalosporium* stripe and tan spot are most severe in continuous wheat where they carry over on wheat residue and infect the wheat the following season. Rotation of wheat with fallow or other non-cereal crops will reduce the risk from these diseases.
- The higher yield potential and per acre value of irrigated wheat influences the management practices of diseases. Growers are more likely to treat irrigated winter wheat with fungicides to protect from leaf rust because of the increased value. Also, certified seed production fields would benefit from foliar fungicide treatment through improved seed quality and health.
- Wheat is subjected to many diseases through continuous cropping, as increased pressure from *Fusarium* head blight (scab) and leaf spotting diseases as well as possible increased insect pressure make continuous production prohibitive.
- *Fusarium* head blight can also be a significant problem in fields planted into corn stubble, as the *Fusarium* fungus is present in the decaying corn residue. Therefore, the usual practice is to place the wheat crop following the soybeans in a three-year rotation or following fallow or a non small grain in other production systems.

**Table 2. Cultural practices that influence wheat diseases (adapted from Univ. Nebraska Cooperative Extension Publication EC95-1873).**

Cultural practice	Diseases influenced	Best Management Practice	Other control options
Cultivars	rusts	resistant varieties	foliar fungicide
	soil-borne mosaic	resistant varieties	proper planting date
Seed quality	loose smut, common smut, scab, black point	certified seed	seed treatment fungicide
Seedbed	root / crown rot	firm/mellow seedbed, proper planting date	seed treatment fungicide
Planting date	root / crown rot	firm/mellow seedbed, proper planting date	seed treatment fungicide
	wheat streak mosaic	proper planting date, post-harvest weed control	tolerant varieties
	High Plains virus	proper planting date, post-harvest weed control	none
	soil-borne mosaic	resistant varieties	proper planting date
	barley yellow dwarf	proper planting date	tolerant varieties
	<i>Cephalosporium</i> stripe	2-year rotation, tolerant varieties	proper planting date
Residue management, post-harvest weed control	tan spot, Septoria diseases	foliar fungicide, rotation	stubble mulching
	<i>Cephalosporium</i> stripe	2-year rotation, tolerant varieties	proper planting date
	wheat streak mosaic High Plains virus	proper planting date, post-harvest weed control	tolerant varieties



### Severity and Losses

The following listed diseases have an estimate of loss due to disease development in wheat planted and harvested in 2003 in South Dakota. The listing includes the common name of the disease followed by the scientific name of the pathogen and estimated percent loss due to each disease.

<b>Table 3. Losses due to disease in South Dakota wheat crop, 2003</b>			
<b>Disease</b>	<b>Pathogen</b>	<b>Crop Loss (%)</b>	
		<b>Spring Wheat</b>	<b>Winter Wheat</b>
Fusarium head blight	<i>Gibberella zeae</i> / <i>Fusarium graminearum</i>	3.00	0.05
Common root and crown rot	<i>Cochliobolis soorikinearum</i> / <i>Bipolaris sativus</i>	7.00	2.00
Dryland root rot	<i>Fusarium graminearum</i>	1.00	5.00
Tan spot	<i>Pyrenophora tritici-repentis</i>	2.00	4.00
Leaf rust	<i>Puccinia tritici</i>	2.00	4.00
Stripe rust	<i>Puccinia striiformis</i>	0.05	3.00
Barley yellow dwarf	<i>BYD luteovirus</i> – aphid transmitted	1.00	0.05
Septoria leaf blotch complex	<i>Septoria tritici</i> / <i>S. avenae</i> / <i>S. nodorum</i>	2.00	3.00
Weather related	Environmental factors	2.00	0.01
Wheat streak mosaic	<i>WSM bromovirus</i> – mite transmitted	0.05	1.00
Loose smut	<i>Ustilago tritici</i>	0.01	0.01
Wheat soilborne mosaic	<i>WSbM furovirus</i> – fungus transmitted	0.00	0.00
Bacterial black chaff	<i>Xanthomonas campestris</i> pv <i>translucens</i>	0.00	0.00
Common bunt / covered smut	<i>Tilletia caries</i> / <i>T. foetida</i>	0.01	0.05
Take-all	<i>Gaeumanomyces graminis</i> var <i>tritici</i>	0.01	0.50
Powdery mildew	<i>Erysiphe graminis</i> f. sp. <i>tritici</i>	0.00	0.00
Septoria glume blotch	<i>S. nodorum</i>	0.00	0.00
Stem rust	<i>Puccinia graminis</i> f.sp. <i>tritici</i>	0.00	0.05
Eyespot (footrot)	<i>Pseudocercospora herpotrichoides</i>	0.00	0.00
Sharp Eyespot	<i>Rhizoctonia cerealis</i>	0.00	0.00
<b>Total loss due to disease in 2003</b>		<b>20.13</b>	<b>22.72</b>

### Resistance Management for Fungicides

Resistance to certain fungicides can develop as selection pressure is placed on the population of the fungal plant pathogens in the environment. We exert this selection pressure by frequent or repeated use of the same fungicide or a fungicide with the same mode of action, often with repeated applications in the same growing season. To manage the risk of fungicides losing their effectiveness, adopt a fungicide resistance management strategy. Many factors can affect how rapidly resistance develops, but a general scheme is described.

To minimize the risk of developing fungicide resistance to strobilurin fungicides follow these recommendations if the crop receives more than three fungicide applications:

- Only use strobilurins preventatively.
- Apply only at manufacturer's recommended rates.
- Do not exceed 30-50% of the total number of applications with strobilurins.
- Continue alternating fungicide modes of action with successive crops.

Strobilurin fungicides include: azoxystrobin (Quadris), pyraclostrobin (Headline), and trifloxystrobin with propiconazole (Stratego).

Triazole fungicides all have a similar mode of action by inhibiting the production of sterol compounds in the fungus and include: propiconazole (Tilt, PropiMax, and Bumper) and tebuconazole (Folicur).

The development of resistance to protectant fungicides such as the carbamates is very rare among plant pathogenic fungi: mancozeb (Dithane, Manex, Manzate, and Penncozeb), the organic aromatic compound chlorothalonil (Bravo), and the inorganic copper and sulfur fungicides.

### **Importance of Various Wheat Diseases as Identified at Planning Meeting**

- Leaf spotting diseases – Considered of high importance across the region, particularly with durum
- Wheat streak mosaic virus- The number one disease in Nebraska, so importance of research is high
- Barley yellow dwarf virus- Important disease in North Dakota and Minnesota where it is a problem, can be devastating, minor in Nebraska, more severe as you go north
- Root rot complex- Identified as a growing issue, number two in importance to Nebraska production, associated with increased stresses, common in conjunction with wheat streak mosaic, more significant in western areas, problem with drought and dry soils at planting – harder to get good seed/soil contact (loose soil leads to root rot infection), more continuous cropping in northern regions is also increasing the prevalence.
- Loose Smut and common bunt- A reemergence of this disease was noted in Nebraska and South Dakota winter wheat production areas
- Bacterial black chaff– In Minnesota and North Dakota is a sporadic disease, but under cool, wet conditions can be bad but not much available to control, some varietal differences are present.
- Powdery mildew – low to negligible in importance
- Wheat soil borne mosaic– Identified as a minor problem in eastern Nebraska, not in western part due to moisture, southern extremes of region
- Aster yellows- Importance is unknown in eastern North Dakota and Minnesota – we don't have a good handle on disease importance. A need for research for this disease was noted.

## **Economic Impact of Fungicide Use in Wheat Production**

Observations from research results and commercial wheat fields in North Dakota indicated the following:

- Fungicide use, applied at heading with angled sprays, resulted in +11.9 bushels yield and +1.3 lb. test weight for tebuconazole, and +8.9 bushels yield and +1.0 lb. test weight with propiconazole on treated wheat acres.
- On treated acres, increased yield from fungicide use was +11.3 million bushels of wheat. Total economic gain was \$33.9 million dollars, based on \$3.00/bu wheat and yield response alone.

The total cost of fungicide application for the available fungicides was \$14.00/acre, or \$14 million for the 1 million acres treated. Total economic return for wheat producers in North Dakota and northwest Minnesota in 1998 from use of the Section 18 and Section 24C fungicides and their improved application showed a \$33.9 million return - \$14.0 million cost = \$19.9 million dollars. The long-term value of continued availability of pesticides such as tebuconazole, cannot be overlooked.

## **General Disease Management Trends**

Intensive Wheat Management is a concept in wheat production that is growing in popularity in the region, especially in South Dakota. Within the concepts of intensive wheat management, pest control, including disease management is critical. This management practice may be driving up fungicide use in wheat production in certain areas of the region. The common practice in this management scheme is to use a fungicide twice, once to protect the early vegetative leaves and flag leaf (products include Quadris, Tilt, Stratego) and one later application to prevent scab infection (Folicur is the only product registered).

## **Rust Diseases**

1. **Leaf rust** *Puccinia triticina* (= *P. recondita* Roberge ex Desmaz. f. sp. *tritici*.) on spring wheat, winter wheat and durum)
  - a) Life Cycle:
    - i) Leaf rust is a disease that does not generally overwinter to a great extent in the northern US. The source of inoculum is generally from overseasoning mycelium or spores on volunteer plants or on crops grown in the southern US.
    - ii) Windborne transport of spores (urediniospores, asexual) by wind is the primary inoculum source to the area.
    - iii) Overwintering spores (teliospores) are effectively a dead end, as the alternate host (meadow rue) is not present in the Northern Great Plains.
    - iv) Leaf rust typically appears in late June to early July and develops from the south to the north across the region. It is expressed as small, oval, orange-yellow pustules on wheat leaves.
    - v) Development is favored by mild to warm days (70's and 80's F) and mild nights (low

- to mid 60's F), with adequate moisture for night time dew development. Wind enhances urediniospore dispersal during the day; cooler nights enhance dew formation. Windborne spores involved in interregional transport are rain deposited.
- vi) Many races of rust occur each year. Varietal reaction ratings are available within each state.
- b) Distribution and importance:
- i) Occurs worldwide wherever wheat is grown. It is most important where dews are frequent during the jointing through flowering stages and temperatures are mild to warm.
  - ii) Leaf rust is a reemerging disease concern as a virulence shift in the rust population races have resulted in many varieties losing their resistance, and now most varieties grown are susceptible to one or more of the prevalent races of leaf rust. Some of the more recently released cultivars with better tolerance of *Fusarium* head blight are more susceptible to the currently prevalent "T" races of leaf rust.
  - iii) Variable from state to state and year to year in this region. As move east to west, treatment declines due to environmental and economic reasons. Yield potential and economics play a huge role in whether or not rust is treated. A 40 bushel yield potential is trigger. Part of a leaf disease complex that is treated. More of a problem in spring wheat and winter wheat. Winter wheat depends on when the inoculum arrives in comparison to crop development.
- c) Cultural Control:
- i) Practices that promote healthy, vigorous wheat plants can help in reducing the impact of the rust infection by providing adequate healthy leaf tissue to maintain photosynthesis throughout the disease cycle.
  - ii) Timing of planting to avoid rust infection periods can be a variable in effectiveness.
  - iii) Rotation and tillage have little effect on the rust diseases. Cool soils in no-till spring wheats can delay crop development and increase risk of exposure to disease.
  - iv) Timing of irrigation during the day can be a factor, early irrigation better to allow plants to dry out during day.
- d) Non-chemical control:
- i) Leaf rust is managed primarily through the use of resistant spring wheat cultivars. Most widely grown spring wheat cultivars were resistant to moderately resistant to leaf rust, although this resistance has diminished in recent years due to race shifts in the pathogen. Variety selection for rust resistance is not a primary factor for winter wheat – weather conditions and elevation are more important.
  - ii) Slow-rusting cultivars that delay the development of rust pustules after the initial rust infection are being researched. The intent is to allow adequate physiological development before significant leaf area is lost.
- e) Chemical Control:
- i) Foliar fungicides are available but require early disease detection and treatment before disease is severe.
  - ii) Fungicide sprays containing mancozeb or propiconazole can control leaf rust. Applications should be made at the early boot stage for mancozeb products, at flag leaf emergence for propiconazole products. Triadimefon products are no longer labeled for use.

## 2. **Stem rust** (*Puccinia graminis* Pers.:Pers. f. sp. *Tritici* Eriks. E. Henn.)

### a) Life Cycle

- i) The primary source of inoculum for stem rust is windblown spores (urediniospores, asexual) from earlier maturing wheat from the southern US and further south. Mycelium or spores on volunteer wheat are also sources of inoculum in tropical and subtropical climates.
- ii) Sexual reproduction on the alternate host, *Berberis vulgaris* (barberry) is currently rare due to barberry eradication in the 1930's, but historically it was an important source of inoculum in northern North America and Europe. However, barberry is reestablishing in many areas.
- iii) Spores germinate when in contact with free water. Infection occurs by penetration through the stomata. Penetration requires at least a low light intensity. Germination optimum is 64 F; latent period varies from 10 to 15 days in the field with temperatures of 59-86 F.
- iv) Unlike leaf rust, stem rust is favored by hot days and mild nights with adequate moisture for nighttime dews. Rain is necessary for effective deposition of spores involved in regional spore transport. Stem rust can survive in relatively dry conditions that limit the development of other rusts.
- v) Stem rust is expressed as brick-red lesions with ragged edges on any and all above ground plant parts (leaf sheaths, true stem, and spike). Pustules can appear on the leaves if other diseases have not killed leaf surfaces. Uredinia are brick red in color and can be seen to rupture the host epidermis, on the leaves uredinia generally penetrate to sporulate on both surfaces. Infected areas are rough to the touch and ragged at the edges of the lesions.
- vi) Stem rust would be expected to appear in mid-June on spring wheats or sooner on winter wheat in South Dakota, with the progression happening earlier in NE and slightly later in ND.

### b) Distribution and Importance

- i) Occurs worldwide wherever wheat is grown. It is most important where dews are frequent during and after heading and temperatures are warm, 18-30 C.
- ii) Yield losses have the potential to be severe (50 to 70%) over a large area and individual fields can be totally destroyed. Damage is greatest when the disease becomes severe before the grain is completely formed. Grain is shriveled due to the damage to the conducting tissue, resulting in fewer nutrients being transported to the grain. Severe disease can cause straw breakage, resulting in a loss of spikes with combine harvesting.
- iii) Has potential to reemerge as the most severe wheat disease in the Plains.
- iv) Has been managed well with resistant varieties to this date.

### c) Cultural Control

- i) Practices that promote healthy, vigorous wheat plants can help in reducing the impact of the rust infection by providing adequate healthy leaf tissue to maintain photosynthesis throughout the disease cycle.
- ii) Rotation and tillage have little effect on the rust diseases.
- iii) Cool soils in no-till spring planted wheats can delay crop development and increase risk of exposure to disease.

### d) Non-Chemical Control

- i) Stem rust is primarily managed through use of resistant cultivars. Most spring planted wheat cultivars in the Northern Great Plains carry good to excellent resistance to stem rust. Winter wheat cultivars vary in stem rust resistance, with resistance on average less than that found in the spring wheat cultivars.
  - e) Pesticides
    - i) Foliar fungicides are available, but are not used for this target pest because of the continued success of host resistance.
    - ii) Fungicides available are identical to those for leaf rust, with the exception that the inorganic copper fungicides are not effective against stem rust.
3. **Stripe Rust** (*Puccinia striiformis* Westend.)
- a) Life Cycle:
    - i) Stripe rust is a relatively new disease of importance to the Northern Great Plains, having caused economic damage only in the past several years.
    - ii) The disease does not overwinter in the northern US. The only source of inoculum is windborne transport of spores (urediniospores, asexual).
    - iii) Overwintering spores (teliospores) are a dead end for the disease, as the alternate host is unknown.
    - iv) Stripe rust typically appears early in the season and develops from the south to the north across the region. It is expressed as small, yellowish pustules that develop in rows, or stripes on the wheat leaves.
    - v) Stripe rust has the potential to significantly reduce photosynthetic area of the leaf. This can dramatically affect yield and seed size and development. On spring planted wheat, due to earlier crop stage at infection, there is a greater potential for yield loss.
    - vi) Development is favored by cool to cold, wet weather. Wind enhances urediniospore dispersal during the day; calm nights enhance dew formation. Free water on the leaf is needed for infection. Windborne spores involved in interregional transport are rain deposited.
  - b) Distribution and importance:
    - i) It is most important where dews are frequent during the jointing through flowering stages and temperatures are cool to cold (list temps). Hot dry weather slows the progression of the disease.
    - ii) Stripe rust has caused significant economic damage in recent years in South Dakota and the surrounding region. The disease is widespread throughout the region, but sporadic in nature.
  - c) Cultural Control:
    - i) Practices that promote healthy, vigorous wheat plants can help in reducing the impact of the rust infection by providing adequate healthy leaf tissue to maintain photosynthesis throughout the diseases cycle.
    - ii) Rotation and tillage have no effect on the rust diseases.
  - d) Non-chemical control:
    - i) Stripe rust may be managed through the use of resistant spring wheat cultivars. Stripe rust resistance reactions have not fully been described in the region.
  - e) Chemical Control:
    - i) Foliar fungicides are available but require early disease detection and treatment before disease is severe. Since strip rust generally occurs early in the season,

management of fungicide use to maintain the availability of later applications could be problematic.

## **Pesticides for Rust Diseases**

### **1. Strobilurins**

- a) Azoxystrobin (Quadris Flowable) at 6.2-10.8 fl oz/A
  - i) REI 12 hrs
  - ii) PHI 45 d for grain/straw
  - iii) PHI 14 d for hay
  - iv) Not used much due to its price – expensive
  - v) Efficacy – excellent
  - vi) Don't want to apply late – can increase mycotoxins from scab.
  - vii) Do not harvest treated wheat for forage
  - viii) Apply prior to disease development from jointing up to late head emergence (Feekes 10.5). Critical from a resistance standpoint for fungicide resistance in accordance with FRAC guidelines.
  - ix) Azoxystrobin is highly effective against rusts and the leaf spot complex.
  - x) Resistance management
    - (1) Do not apply more than 0.77 quarts product per acre per season
    - (2) Do not make more than two applications per season to minimize resistance
- b) Pyraclostrobin (Headline) at 6-9 fl oz/a
  - i) PHI 14 d for wheat hay. Do not apply later than early flowering (Feekes 10.5)
  - ii) Used at lower rates, sometimes lower than labeled rates. From a resistance management standpoint, this is not recommended (FRAC guidelines).
  - iii) Efficacy – excellent
  - iv) Most reasonably priced product available for stripe rust (2003).
  - v) Apply before the disease becomes severe.
  - vi) Apply at 7-10 d intervals starting at early boot
    - (1) Maximum of two applications and 18 fl oz/A per season – most growers only apply once per season.

### **2. EBDC (carbamate) Fungicides**

- a) Mancozeb (Dithane (various formulations), Manex II, Manzate, Penncozeb at 1-2 lb/acre, depending on product)
  - i) PHI 26 d
  - ii) Efficacy – good as long as spores aren't present at application time, short residual – less than competitive products. Not rain fast.
  - iii) Not used much, only preventative. May be tank mixed with herbicides.
  - iv) Inexpensive
  - v) Desirable in a resistance management program. No known resistance to this product – multiple modes of action.
  - vi) Do not graze livestock on treated acres prior to harvest
  - vii) Apply before disease onset, tillering, or jointing state and repeat at 7-10 d intervals
    - (1) Do not make more than three applications per season or apply after Feekes 10.5 (heading)

- (2) Rarely is more than one application made.
- (3) Not specifically labeled for stem or stripe rust, only leaf rust
- (4) Use Latron CS-7 surfactant to improve product performance
- b) Mancozeb plus surfactant (Dithane DF Rainshield at 2.1 lbs/acre or Dithane F-45 Rainshield at 1.6 qts/acre)
  - i) Limitations same as Mancozeb above
  - ii) More weather resistant.
- 3. Triazoles
  - a) Propiconazole (Tilt 3.6 EC, PropiMax and Bumper) at 2-4 fl oz/a
    - i) REI 24 hr
    - ii) PHI 40 d
    - iii) Efficacy – excellent
    - iv) Used at lower rates due to cost - \$10/A at 4 fl oz/A rate (2003).
    - v) Intensive wheat management is driving an increase in use in certain areas (maybe move to production practices section).
    - vi) Small percent of acres treated, use higher in the east to northeast part of region.
    - vii) Do not graze or feed treated crops to livestock or cut green crop for hay or silage. Straw after harvest may be used for bedding or feed.
    - viii) This fungicide is locally systemic and is effective against rusts and the residue-borne leaf spot diseases. It is typically applied once to the fully emerged flag leaf. Some producers are using a reduced rate application at the five leaf stage to reduce tan spot and Septoria diseases early in the season.
    - ix) Limited to two applications per year
    - x) Do not apply after heading
    - xi) Use a minimum of 5 gal/A by air or 15 gal/A by ground (PropiMax) or 10 gal/A (Tilt)
    - xii) This systemic fungicide is mainly protectant in nature, but has some limited curative properties
  - b) Tebuconazole (Folicur) at 4 fl oz/A
    - i) PHI 28 d
    - ii) Efficacy – excellent
    - iii) Small percent of acres treated but most widely used fungicide in ND and SD. Not labeled for or generally used for rust specifically, but is a benefit from scab treatment.
    - iv) Used at full labeled rate (4 fl oz/A)
    - v) Folicur is a systemic curative and protectant fungicide
    - vi) Currently available only as a Section 18 product in SD, ND, MN, MT and MI.
- 4. Triazole plus strobilurin (trifloxystrobin plus propiconazole) (Stratego) at 5-10 fl oz/A
  - a) REI 2 d
  - b) Efficacy – excellent
  - c) More costly than triazoles (@ 50cents/A more)
  - d) Only available the last 1-2 years.
  - e) Small percentage of acres treated.
  - f) PHI 35 d
    - i) If one application (10 fl oz/A), do not graze or feed for 30 d
    - ii) If two applications (20 fl oz/A), do not graze or cut for forage or hay
  - g) Begin preventative applications when conditions favor disease
  - h) A second application may be made 14 d following the first



- i) Maximum of two applications per year
- j) Use a minimum of 5 gal/A by air or 15 gal/A by ground
- 5. Inorganics
  - a) Copper products (Various)
    - i) PHI- usually no limitations
    - ii) Efficacy – fair to good, residual very short
    - iii) Organic alternative
    - iv) More effective on leaf spotting diseases than on rusts.
    - v) Rarely used.
- 6. Pipeline Products: Quilt (Propiconazole plus azoxystrobin) at 14 fl oz/A is available in 2004. Excellent control expected. Apply earlier (up to Feekes 9). Other triazoles and other strobilurins are being developed. Registration of triazoles is dependent on outcome of triazole review.
- 7. “To Do” List
  - a) Research
    - Horizontal resistance, minor gene resistance, slow rusting need further investigation
    - Need more information on stripe rust, including resistance ratings
    - Need validation of existing models for diseases, weather data station expansion and access to information
    - Barberry monitoring and correlation to diseases
  - b) Education/Extension
    - None listed
  - c) Regulatory
    - Sec 3 label for more triazoles is a critical need.

## Leaf Spotting Diseases

1. Disease Organisms
  - a) **Tan spot** (*Pyrenophora tritici-repentis* on wheat and durum)
  - b) **Septoria leaf disease complex** (*Septoria tritici*, *S. avenae*, *S. nodorum* on wheat)
  - c) **Spot blotch** (*Helminthosporium sativum*)
2. General Information
  - a) These are all relatively common leaf diseases in wheat in The Northern Great Plains.
  - b) If enough leaf surface area is killed, grain yields and test weights are reduced.
3. Life Cycle
  - a) Tan spot, the three *Septoria* diseases, Spot blotch and Powdery mildew are all residue-borne.
  - b) The diseases will typically appear in the spring during cool, wet weather. Most of these diseases require long periods of high moisture and high humidity for infection to occur.
  - c) Seedling infection may occur on spring-seeded grain, but is typically less severe than on fall-seeded wheat.
  - d) Seedling disease of spring grains will usually occur in May and June with more serious flag leaf infections developing in midsummer. For fall-seeded wheat, seedling infection takes place in the fall, with development of more severe disease symptoms occurring early in the following growing season

- e) Tan spot and *Septoria* are expressed as yellow, tan, or brown spots on lower leaves, usually small but enlarging with time. Tan spot lesions will develop a diamond shape as they mature while *Septoria* lesions are more random in shape.
4. Distribution and Importance
    - a) Damage from these diseases is due to the loss of photosynthetic area and water loss from the damage to the leaf tissue.
    - b) Under favorable environmental conditions, these diseases can be quite severe. Although economic loss probably occurs every year in certain areas, severe outbreaks tend to be sporadic in nature.
    - c) On spring wheat can lose 30-40% yield if disease is present and have favorable conditions. Test weight concerns also (5% reduction).
  5. Cultural Control
    - a) These diseases are managed by rotation, tillage, and resistant cultivars.
    - b) Tillage prior to planting with the purpose of burying crop residue can reduce leaf diseases by reducing inoculum availability from plant residues.
    - c) Hot, dry weather often stops or slows disease development while rainy or humid weather increases disease spread and severity.
  6. Non-Chemical Control
    - a) Most varieties are susceptible to tan spot and *Septoria* blotch, but there are notable differences in reaction. Some research into tan spot resistance is currently taking place.
  7. Pesticides
    - a) Most foliar fungicides containing mancozeb or propiconazole or other strobilurins are effective against foliar leaf diseases. Foliar fungicides require early disease detection and treatment. Timing is critical especially for protectant products.
    - b) Fungicides are available for use against tan spot and the *Septoria* complex, but are not commonly used against powdery mildew in the Northern Great Plains.

## **Fungicides for Leaf Spotting Diseases**

1. EBDC (carbamate) Fungicides
  - a) Mancozeb (Dithane M-45, Manex II, Manzate, Penncozeb and other formulations at 1-2 lb/acre, depending on product)
    - i) PHI 26 d
    - ii) Efficacy – good if applied on a timely basis, protectant only – no curative
    - iii) Low use due to other products being available – other products are product of choice for other diseases
    - iv) Potential for resistance management if other products are not available
    - v) Do not graze livestock on treated acres prior to harvest
    - vi) Apply at disease onset, tillering, or jointing state and repeat at 7-10 d intervals
      - (1) Do not make more than three applications per season or apply after Feekes 10.5 (heading)
      - (2) Use Latron CS-7 surfactant to improve product performance
  - b) Mancozeb plus surfactant (Dithane DF Rainshield at 2.1 lbs/acre or F-45 Rainshield at 1.6 qts/acre)
    - i) Limitations same as Mancozeb above

2. Triazoles
  - a) Propiconazole (Tilt 3.6 EC, PropiMax and Bumper) at 2-4 fl oz/a
    - i) REI 24 hr
    - ii) PHI 35 d
    - iii) Efficacy – excellent
    - iv) 2 oz rate added to herbicides if weather conditions are favorable for disease at 4-5 leaf stage – spring wheats only
    - v) Second most widely used fungicide in the area
    - vi) Do not graze or feed treated crops to livestock or cut green crop for hay or silage. Straw after harvest may be used for bedding or feed.
    - vii) This fungicide is locally systemic and is effective against rusts and the residue-borne leaf spot diseases. It is typically applied once to the fully emerged flag leaf. Some producers are using a reduced rate application at the five leaf stage to reduce tan spot and Septoria diseases early in the season.
    - viii) Limited to two applications per year
    - ix) Use a minimum of 5 gal/A by air or 15 gal/A by ground
    - x) Tilt is not specifically labeled for spot blotch control.
3. Strobilurins
  - a) Pyraclostrobin (Headline) at 6-9 fl oz/a
    - i) PHI 14 d for wheat hay, essentially 35 d for harvest
    - ii) Efficacy – unknown, newer product
    - iii) Not used much, for the price it isn't as good as Tilt
    - iv) Resistance concern if rotational crops use strobilurins
    - v) Apply at 7-10 d intervals starting at early boot
      - (1) No application after flowering
      - (2) Maximum of two applications and 18 fl oz/A per season
  - d) Azoxystrobin (Quadris Flowable) at 6.2-10.8 fl oz/a
    - i) REI 12 hrs
    - ii) PHI 45 d for grain/straw
    - iii) PHI 14 d for hay
    - iv) Efficacy – good to excellent, newer product
    - v) Not used much, price is a factor
    - vi) Do not harvest treated wheat for forage
    - vii) Apply prior to disease development from jointing to late heading
    - viii) Azoxystrobin is highly effective against rusts and the leaf spot complex. It may also be used to suppress Fusarium head blight.
    - ix) Resistance management
      - (1) Do not apply more than .77 quarts product per acre per season
  - b) Do not make more than two applications per season
4. Triazole plus strobilurin (Trifloxystrobin plus propiconazole) (Stratego) at 5-10 fl oz/A
  - i) PHI
    - (1) If one application (10 fl oz/A), do not graze or feed for 30 d
    - (2) If two applications (20 fl oz/A), do not graze or cut for forage or hay
  - ii) Efficacy – good to excellent
  - iii) 5 oz rate is sometimes mixed with broadleaf herbicides
  - iv) slightly more expensive but has two modes of action, so is used

- v) Begin preventative applications when conditions favor disease, does have some curative
  - vi) A second application may be made 14 d following the first
  - vii) Maximum of two applications per year, but used only once by growers
  - viii) Use a minimum of 5 gal/A by air or 15 gal/A by ground
5. Inorganics
- a) Copper products (Various)
    - i) PHI- usually no limitations
    - ii) Organic grower option
    - iii) Efficacy – fair, if used for organic production need to be used on a shorter interval and applied more than once
    - iv) Most effective on Septoria diseases.
    - v) Rarely used, but can be applied on a 7-10 day interval, beginning at early boot.
6. Pipeline Products: Folicur (tebuconazole, a triazole) and Quilt (propiconazole plus azoxystrobin, a triazole plus a strobilurin)
7. “To Do” List
- a) Research
    - i) Regional screening program for standardized varietal rating
    - ii) Modeling and weather stations available data
  - b) Education/Extension
    - i) Modeling and weather stations available data
    - ii) Wider availability of forecasting models
  - c) Regulatory
    - i) Folicur registration on a Section 3 label, preferably

## Other Fungal Diseases

1. **Powdery mildew** (*Erysiphe graminis* f. sp. *Tritici*)
- a. General Information
    - i. Powdery mildew is not usually a great concern in spring planted grains, but can be severe in winter wheat.
    - ii. If enough leaf surface area is killed, grain yields and test weights are reduced.
  - b. Life Cycle
    - i. Powdery mildew is overwinters as mycelia on green plant tissue or as small, hard, black mats of mycelia (microsclerotia).
    - ii. The disease will typically appear in the spring during cool, wet weather. The disease requires relatively long periods of high moisture and high humidity for infection to occur.
    - iii. Seedling infection may occur on spring-seeded grain, but is typically less severe than on fall-seeded wheat.
    - iv. Seedling disease of spring grains will usually occur in May and June with more serious flag leaf infections developing in midsummer. For fall-seeded wheat, seedling infection takes place in the fall, with development of more severe disease symptoms occurring early in the following growing season
    - v. Powdery mildew is expressed as gray to white, cottony growth over the leaf

surface

- c. Distribution and Importance
  - i. Damage from these diseases is due to the loss of photosynthetic area increased respiration and transpiration in the leaf.
  - ii. Severe damage from this disease is not common in the Northern Great Plains, but can occur under ideal environmental conditions.
- d. Cultural Control
  - i. These diseases are managed by rotation, tillage, and resistant cultivars.
  - ii. Hot, dry weather often stops or slows disease development while rainy or humid weather increases disease spread and severity.
  - iii. For powdery mildew, avoiding excessive nitrogen fertilization, and thereby avoiding a lush, overgrown canopy, can reduce disease severity.
- e. Non-Chemical Control
  - i. Planting varieties resistant to powdery mildew can be used to control this disease.
- f. Pesticides
  - i. Foliar fungicides containing strobilurins or triazole compounds are effective against powdery mildew. Foliar fungicides require early disease detection and treatment.
  - ii. Fungicides are not commonly used against powdery mildew.

### **Fungicides Registered Against Powdery Mildew**

#### **1. Strobilurins**

- a) Azoxystrobin (Quadris Flowable) at 6.2-10.8 fl oz/a
  - i) REI 12 hrs
  - ii) PHI 45 d for grain/straw
  - iii) PHI 14 d for hay
  - iv) Do not harvest treated wheat for forage
  - v) Apply prior to disease development from jointing to late heading (Feekes 10.5)
  - vi) Azoxystrobin is highly effective against rusts and the leaf spot complex. Resistance management
    - (1) Do not apply more than .77 quarts product per acre per season
    - (2) Do not make more than two applications per season for resistance management
- b) Pyraclostrobin (Headline) at 6-9 fl oz/a
  - i) PHI 14 d for wheat hay
  - ii) No application after flowering (Feekes 10.53)
  - iii) Maximum of two applications and 18 fl oz/A per season

#### **2. Triazoles**

- a) Propiconazole (Tilt 3.6 EC, PropiMax and Bumper) at 2-4 fl oz/a
  - i) REI 24 hr
  - ii) PHI 40 d
  - iii) Do not graze or feed treated crops to livestock or cut green crop for hay or silage. Straw after harvest may be used for bedding or feed.
  - iv) This fungicide is locally systemic and is effective against rusts and the residue-borne leaf spot diseases. It is typically applied once to the emerging flag leaf (Feekes 8).

- v) Do not apply after heads emerge
- vi) Use a minimum of 5 gal/A by air or 15 gal/A by ground
- 3. Triazole plus strobilurin (trifloxystrobin plus propiconazole) (Stratego) at 5-10 fl oz/A
  - a) PHI 35 d
    - i) If one application (10 fl oz/A), do not graze or feed for 30 d
    - ii) If two applications (20 fl oz/A), do not graze or cut for forage or hay
  - b) Begin preventative applications when conditions favor disease
  - c) A second application may be made 14 d following the first
  - d) Use a minimum of 5 gal/A by air or 15 gal/A by ground
- 4. Inorganics
  - a) Sulfur products (Various)
    - i) REI Refer to product labels
    - ii) PHI- None listed
    - iii) Elemental sulfur can be used to control powdery mildew. Avoid application during high temperatures or plant injury may occur
    - iv) Rarely used except in research greenhouse settings.
- 5. Pipeline Products: Quilt
- 6. “To Do” List
  - a) Research: None listed
  - b) Education/Extension: None listed
  - c) Regulatory: None listed

***Fusarium* head blight or scab** (*Gibberella zeae* / *Fusarium graminearum* on wheat and durum)

1. Life Cycle
  - a. This disease has been a significant concern for spring wheat and durum growers in the Northern Great Plains for the past decade.
  - b. At this time, scab is the most serious fungal disease of cereal grains in the Northern Great Plains.
  - c. *Fusarium* head blight or scab is a much greater concern to spring-grown grain than to fall-seed grain such as winter wheat. Winter wheat generally avoids the primary scab infection period by flowering earlier in the growing season than the spring-seeded wheats.
  - d. *Fusarium* is a residue-borne disease, overwintering on crop residue such as wheat residue as well as corn fodder and other plant material.
  - e. *Fusarium* is most severe in minimum tillage or zero tillage fields or on wheat fields planted into corn residue.
  - f. Infection occurs in the wheat plant primarily through the open flowers.
  - g. Infection is favored by a prolonged period of warm, wet weather at flowering, perhaps as long as 36 hours. Warm nighttime temperatures are a key in severe scab development.
  - h. *Fusarium* head blight is expressed as white spikelets or entire white heads. Pink to salmon colored masses of spores may develop at the base of infected spikelets during humid weather.
  - i. The disease also infects seeds, and can severely limit the usefulness of the harvested

grain due to the presence of varying levels of a toxin, deoxynivalenol (DON) in the seed.

2. Distribution and Importance
  - a. *Fusarium* is widespread in the spring-seeded wheat growing areas, particularly where continuous wheat cropping or minimum tillage is practiced.
  - b. Reduced yields and quality (up to 100%) and especially reduced value to the seed crop from seed damage can lead to extensive monetary loss if infection is severe. DON tolerance levels (2 ppm – food grade) are built into the grain industry – whole loads may be rejected. Grading aspect is visual and is determined by kernel damage.
  - c. Occurs every year in this region. More severe when rotated after corn or after wheat.
3. Cultural Control
  - a. *Fusarium* head blight is managed culturally by rotation and tillage to bury crop residue and trash.
  - b. Any practice that extends the rotation away from a susceptible small grain crop (away from a wheat or barley crop) will aid in disease reduction through reduced inoculum.
  - c. Management of corn residue prior to a wheat crop is also critical, since *Fusarium* infects nearly all corn plants to some extent.
  - d. Scabby grain should not be used for seed.
4. Non-Chemical Control
  - a. No spring wheat cultivars are resistant to the disease.
  - b. Screening and breeding programs have identified varietal differences in tolerance to *Fusarium*.
5. Pesticides
  - a. Fungicides have been available on a Section 18 Emergency Exemption for application until flowering to suppress *Fusarium* head blight.
  - b. Disease may be reduced by as much as 60% while yield is increased by up to 20% over untreated fields with the application of some fungicides.

### **Fungicides for the control of Fusarium Head Blight**

1. Tebuconazole (Folicur) at 4 fl oz/A
  - a. PHI 28 d
  - b. Efficacy –fair (best product at this time) because the application timing and application coverage are critical (up to @60% suppression) Folicur may result in a difference between a marketable and non-marketable crop.
  - c. Folicur is a systemic curative and protectant fungicide
  - d. Currently available only as a Section 18 product in SD, ND, MN and NE
  - e. Only product labeled in South Dakota for Head Blight/Scab control.
  - f. Provides only suppression of scab.
2. Pipeline Products: prothioconazole (Proline)
3. “To Do” list:
  - a) Research
    - Multiple gene resistance in varieties (more critical for spring and durum wheats)
    - High yielding resistant varieties, current resistant varieties show a yield drag

- compared to conventional varieties
- Transgenic wheat may be being investigated by chemical companies
- Need for improved forecasting model for scab prediction
- Need to expand the data weather network to get specific area weather data
- Application technology for fungicide application and associated efficacy of control of scab
- b) Regulatory
  - Resolve the triazole issue and conclude the triazole review, making some triazoles available on full federal (Section 3) labels
  - Proline registration is a possibility
  - Industry standardization for DON sampling/testing is needed.
- c) Education/Extension
  - Education needed on timing of spraying for growers
  - Predictive models need to be further developed and distributed
  - Application technology (see research section above)

## **Smut Diseases**

### **Loose Smut (*Ustilago tritici*)**

1. Life Cycle
  - a. The fungus survives in the embryo of the infected seed.
  - b. Loose smut will appear soon after heading of the crop, starting about June 1 for early seeded spring wheat and continuing through the month of June.
  - c. Symptoms and signs of the disease are dusty, brown to dark brown or black spore masses replacing the spikelets on the head rachis.
  - d. After the spores have blown away there may remain only a naked rachis with a few remnants of the brown spores.
  - e. Airborne spores lead to the infection of seed in the current growing season.
2. Distribution and Importance
  - a. Loose smut is present nearly every year across the Northern Great Plains.
  - b. Loose smut causes very minor losses each year, with estimates as low as 0.01% yield loss each year.
3. Cultural Control
  - a. Fields with a high incidence of loose smut should not be used as seed without treating with an effective seed treatment fungicide.
  - b. Barley seed can be tested for loose smut with an embryo test; however, the embryo test is unreliable for the detection of loose smut of wheat.
  - c. Crop rotation is recommended for reducing the risk of infection.
4. Non-Chemical Control
  - a. All wheat and durum varieties grown in the Northern Great Plains are susceptible to loose smut. Generally, smut is not a severe problem, but the reduction in use of seed treatment in recent years has resulted in increased numbers of fields with economic losses due to loose smut.
  - b. Avoiding use of seed from contaminated fields can reduce this seed borne disease.



5. Pesticides
  - a. The disease can be managed by treating seed at planting with a systemic seed treatment fungicide, such as carboxin, difenoconazole, or triadimenol.
6. Pipeline Products: None listed
7. “To Do” List
  - a. Research: None
  - b. Education/Extension: None
  - c. Regulatory: None

### **Covered smut and Common bunt (*Tilletia caries*, *T. foetida*)**

1. Life Cycle
  - a. Covered smut and common bunt survive in the embryo of the infected seed or as “balls” of smut spores surrounded by a persistent membrane. Teliospores also persist in the soil.
  - b. Covered smut and common bunt will appear about the same time as loose smut (above), early to mid-June.
  - c. These smut diseases replace the seed with a stiff membrane filled with dark brown or black spore masses.
  - d. Smutted kernels, sometimes called “bunt balls”, are only slightly larger in diameter than healthy seed, but are light brown in color and more round; the smutted kernels, when ruptured, release masses of dark brown to black spores.
2. Distribution and Importance
  - a. Covered smut and common bunt are present nearly every year across the Northern Great Plains.
  - b. Minor losses each year, however, during 2003, the incidence of common bunt rose significantly in the winter wheat production areas, especially in southern Nebraska and in South Central South Dakota.
3. Cultural Control
  - c. Fields with a high incidence of these diseases should not be used as seed without treating with an effective seed treatment fungicide.
4. Non-Chemical Control
  - d. Avoiding use of seed from contaminated fields can reduce this seed borne disease.
5. Pesticides
  - a. The disease can be managed by treating seed at planting with a protectant or systemic seed treatment fungicide.
6. Pipeline Products: None listed
7. “To Do” List
  - a. Research: None
  - b. Education/Extension: None
  - c. Regulatory: None

## **Root Diseases**

### **Common Root Rot (*Cochliobolus sativus* / *Bipolaris sativus*)**

1. Life Cycle
  - a. Common Root Rot is a residue-borne disease that may increase in severity in no-till or when spring and winter wheats are cropped in successive years.
  - b. Common root rot becomes most obvious on spring wheat from heading to maturity, about July 15 to August 15.
  - c. Root rot can be identified by brown discoloration of the roots and crown, and wheat heads having fewer seeds that may be shriveled.
  - d. Affected plants may appear stunted or with stunted tillers.
  - e. White heads that spread down on white stems or prematurely ripe plants may also indicate root rot.
  - f. Affected plants may pull from the ground easily because the roots and crowns are severely rotted. Plants that die prematurely may occur in irregularly shaped clusters or as single plants in a field.
2. Distribution and Importance
  - a. This disease is a potential problem every year in the Dakotas. Damage is often most severe when the crop is stressed.
3. Cultural Control
  - a. Common root rot may be managed with crop rotation. Avoid successive cereal crops.
  - b. Destroy the green bridge of volunteer winter wheat or grassy weeds.
  - c. Slow release forms of nitrogen may also increase the incidence of common root rot.
4. Non-Chemical Control
  - a. Although varietal resistance is not known, varietal differences in ratings for root rot diseases are present.
5. Pesticides
  - a. The disease can be managed by treating seed at planting with seed treatment fungicides.
  - b. Seed treatments containing difenoconazole, imazalil, and triadimenol are registered for suppressing root rot.
6. Pipeline Products: None listed
7. "To Do" List
  - a. Research: None
  - b. Education/Extension: None
  - c. Regulatory: None

### **Take-All (*Gauemanomyces graminis* var. *tritici*)**

1. Life Cycle
  - a. Take-all is a residue-borne disease that may increase in severity in no-till or when spring and winter wheats are cropped in successive years.
  - b. It is most common in fields of continuously cropped wheat and high soil moisture
  - c. Symptoms of take-all, like common root rot will appear starting about the last week of June and continuing through crop maturity.
  - d. Stunted tillers, stunted plants, white heads, and prematurely ripe areas of the field are

- all indicators of possible take-all.
- e. Affected plants will develop a scurfy to glossy black discoloration at the base of the stem. Plants may pull easily from the ground because of severely rotted roots and crowns.
- 2. Distribution and Importance
  - a. Take-all is a serious root rot which can completely destroy a crop.
  - b. Take-all is typically a greater concern on winter wheat than spring wheat.
- 3. Cultural Control
  - a. Take-all is managed with crop rotation and tillage to incorporate residues.
  - b. Wheat should not be planted on a field having take-all for three seasons.
  - c. Take-All suppressive soils have not been observed in the Northern Great Plains.
- 4. Non-Chemical Control
  - a. Although varietal resistance is not known, varietal differences in ratings for root rot diseases are present.
- 5. Pesticides
  - a. The disease can be managed by treating seed at planting with seed treatment fungicides. Seed treatment fungicides effective against common root rot are also effective against take-all, but may require application at the highest labeled rate. Seed treatments containing difenoconazole and triadimenol are registered for control of take-all.
- 6. Pipeline Products: None listed
- 7. “To Do” List
  - a. Research: None
  - b. Education/Extension: None
  - c. Regulatory: None

**Table 4. Registered seed treatment fungicides and their usage in North Dakota wheat, oats, barley and rye production 2003 (from 2003 FIELD CROP FUNGICIDE GUIDE PP-622 (Revised), November 2002, NDSU Extension)**

Chemical	Appl.	Dosage <sup>1</sup>	Disease Control <sup>2</sup>				Remarks
			Covered Smut	Loose Smut	Seedling <sup>3</sup> Blight	Common Root Rot	
<b>Captan + PCNB + Thiabendazole,</b> 19.8% 8.4%:1.0% Rival Flowable	Slurry	4.0 fl oz/cwt			X		Wheat only.
<b>Carboxin</b> Vitavax 34, 34%	Slurry	2-3 fl oz/cwt	X	X			Not registered for rye. Controls smuts.
<b>Carboxin +Captan, 20%:19%</b> Enhance	Drill box	4 oz/cwt	X	X	X		
<b>Carboxin + Maneb DB-Green + Vitavax</b> 20%:35%	Dust or drill box	2 oz/bu	X	X	X		Neither registered for rye.
Enhance Plus, 20%:35%	Drill box	2 oz/bu	X	X	X		DB Green + Vitavax and Enhance Plus contain 18.75% lindane insecticide.
<b>Carboxin + PCNB Vitavax-PCNB,</b> 17%:17%	Slurry or mist	3-4 fl oz/cwt wheat; oats; barley	X	X	X		Not registered for rye
<b>Carboxin + Thiram Vitaflo 280</b> 14.9%:13.2%	Slurry	5 oz/cwt, wheat, barley, oats, 3 oz/cwt triticale	X	X	X		None registered for rye. RTU-Vitavax-Thiram and Vitaflo 280 registered for triticale.  Vitavax T-L registered for wheat only. Vitavax-Thiram-Lindane contains 8% lindane insecticide.
Vitavax 200 Flowable 17%:17%	Slurry or mist	3-4 fl oz/cwt	X	X	X		
RTU-Vitavax-Thiram, 10%:10%	Liquid or slurry	5-6.8 fl oz/cwt	X	X	X		
Vitavax T-L, 10%:10%	Drill box	5-6.8 fl oz/cwt	X	X	X		

Vitavax-Thiram-Lindane, 14%:12%	Slurry	5 fl oz/cwt wheat, oats 6 fl oz/cwt barley	X	X	X		
<b>Carboxin + Imazalil + Thiabendazole</b>  RTU Vitavax Extra 16.7% : 1.2% : 1.5%	Slurry	5 fl oz/cwt wheat	X	X	X	X	For wheat only. Effective against various Helminthosporium and Fusarium species as well as seed-borne Septoria nodorum.
<b>Difenoconazole + Mefenoxam</b> Dividend XL 16.5% : 1.38%	Slurry - concentrated product	1.0 fl oz/cwt common bunt, loose smut, seed-borne Septoria, seed-borne Fusarium, Pythium damping off and seed rot caused by <i>Penicillium</i> and <i>Aspergillus</i> . Partial control of common root rot ( <i>Cochliobolus</i> ) and Rhizoctonia Root Rot.	X (bunt)	X	X	X	<b>For spring and winter wheat only.</b> Do not graze until 55 days after planting. Do not plant any crop other than wheat within 30 days to fields in which treated seeds were planted. For commercial or on-farm use.
Dividend XL RTA 3.21% : 0.2%	Ready to apply	2.0 fl oz/cwt seed borne Septoria, common bunt, loose smut, flag smut, general seed rots, seed-borne Fusarium, Pythium damping off plus partial control of common root rot ( <i>Cochliobolus</i> ) and Rhizoctonia root rot and Take-All.	X (bunt)	X	X	X	
			X (bunt)	X	X	X	

		<p>2.5 fl oz/cwt common bunt, loose smut, Fusarium seed scab</p> <p>5 fl oz/cwt common bunt, loose smut, seed-borne Septoria, general seed rots, seed- borne Fusarium, Pythium damping off, plus partial control of common root rot</p> <p>10 fl oz/cwt - above diseases plus partial control of take- all, common root rot and Rhizoctonia root rot</p>	X (bunt)	X	X	X	
<p><b>Fludioxonil</b> Maxim 4FS, 40.3%</p>	Slurry	0.08-0.16 fl oz/cwt			X		For control of seed-borne and soil-borne fungi which cause seed decay, damping off and seedling blight. Cereal forage may be grazed 30 days after planting.

<b>Imazalil</b> Agsco Double R II Seed Treatment, 10%	Slurry	0.8-1.5 fl oz/cwt			X	X	Not registered for oats or rye. Registered for suppression of common root rot of wheat and barley and for barley stripe. Registered for control of seed borne net blotch and <i>Septoria nodorum</i> . May be used with other fungicides. If used in combination with seed treatment products that contain lindane, treated seed should be planted as soon as possible. Do not graze or feed foliage from treated acres to livestock for 6 weeks after planting.
Flo-Pro IMZ Flowable, 31%	Slurry or on-farm seed treatment	0.25-0.5 fl oz/cwt			X	X	
Nu-Zone 10 ME, 10%	Slurry	0.8-1.5 fl oz/cwt			X	X	
<b>Mancozeb</b> Dithane WSP, 80%	For planter box trtmt. only	Consult labels for appropriate rate for each crop.	X		X		Grain Guard Plus contains 18.75% lindane insecticide.
Grain Guard, 50%	Drill box		X		X		
Grain Guard Plus, 50%	Drill box	Consult label	X		X		
Manzate 75 DF, 75%	Slurry	Consult label	X		X		
Penncozeb 75DF 75%	Planter box trtmt. only		X		X		
Penncozeb 80WP 80%	Planter box trtmt. Only		X		X		
<b>Maneb</b> Agsco DB Green, or Seed Mate Maneb-Lindane (all 50%)	Dust or drill box	2 oz/bu	X		X		Both combined with 18.75% lindane for wireworm control.

Agsco DB-Green L, 25.6%	Auger treater, slurry	3 fl oz/bu	X		X		Contains 8.6% lindane insecticide.
<b>Mefenoxam</b>  Apron XL-LS, 32.3%	Mist or slurry	0.32-0.64 fl oz/cwt			X		For Pythium damping off control.  See label for Dividend- Apron XL-LS combination
<b>Metalaxyl</b> Allegiance FL, 28.35%	Mist or slurry	0.375-0.75 fl oz/cwt			X		For control of Pythium damping off only.
<b>Metalaxyl + PCNB + Carboxin</b>  Prevail, 3.12%:15%:15%	Drill box	3 oz/bu wheat 2-4 oz/bu barley, oats	X	X	X		Not registered for rye. Do not graze treated areas for six weeks after planting. For protection against smuts, Pythium and Rhizoctonia seedling disease complex.
<b>PCNB (Terraclor)</b>  Terra-Coat LT-2N, 23.7%	Liquid or slurry	2 fl oz/bu wheat 2-4 fl oz/bu barley, oats	X		X		Not registered for rye.
RTU-PCNB, 24%	Liquid or slurry	3.75-7.5 fl oz/cwt barley, 5.5-11 fl oz/cwt oats, 3 fl oz/cwt wheat	X		X		Not registered for rye.
PCNB Seed Coat, 24%	Slurry	2-4 oz/bu barley, oats, 2 oz/bu wheat	X		X		Not registered for rye.
<b>Thiram</b>  42-S Thiram, 42%	Liquid or slurry	2 fl oz/bu			X		Not registered for oats
Thiram 50WP Dyed, 50%	Drill box or slurry	3.3 oz/cwt wheat, 4.1 oz/cwt barley, 3.7 oz/cwt rye			X		



<b>Tebuconazole + Metalaxyl</b>  Raxil MD, 0.48%:0.64%  Raxil XT, 15.0%:20%	Slurry or mist  Slurry (wp pouch)	5 fl oz/cwt	X	X	X	X	Not registered for rye. Do not graze barley, wheat, or oat green forage for 31, 31 and 51 days, respectively.
		0.16 oz/cwt or 1 pouch/50 cwt	X	X	X	X	
<b>Tebuconazole + Metalaxyl + Imazalil</b>  Raxil MD Extra, 0.34%:0.58%:1.0%	Slurry or mist	5 fl oz/cwt	X	X	X	X	Not registered for rye or oats.
<b>Tebuconazole + Thiram</b>  Raxil-Thiram, 0.6%:20.0%	Liquid or Slurry	3.5-4.6 fl oz/cwt	X	X	X	X	Not registered for rye. Effective against seed-borne Fusarium and <i>Septoria nodorum</i> . Do not graze wheat or barley for 31 days and oats for 30 days after planting.
<b>Triadimenol</b>  Baytan 30F, 30%	Slurry	0.75 fl oz/cwt for control of smuts. 1.5 fl oz/cwt fl control of seed borne glume blotch and for suppression of take-all, foot rot. 1.5 fl oz/cwt for control of early season foliar disease.	X	X	X		For use only through commercial seed treaters with closed application systems. Green forage may be grazed 40 days after seeding. Information additional to the label indicated that Baytan 30 treated seed should not be planted at depths greater than 1 1/2" and that Baytan 30 should not be used in combination with any seed treatment insecticide, such as lindane.
<b>Triadimenol + Thiram,</b>  RTU-Baytan-Thiram 5.0%:15.3%	Slurry or mist	4.5-9 fl oz/cwt	X	X	X	X	For use with commercial seed treaters, green forage may be grazed 40 days after seeding

<sup>1</sup>Dosage = Amount of formulated product to apply.

<sup>2</sup>X = Product labeled for crop and disease; Blank = product not labeled for specific disease.

<sup>3</sup>Seedling blights due to fungal infections of the seed such as black point and scab.

## Viral and Bacterial Diseases

### **Wheat streak mosaic** (Wheat streak mosaic bromovirus - WSMV), High Plains virus

#### 1. Life Cycle

- a. WSMV, as a virus disease must survive in a living host or a vector to overwinter.
- b. WSMV is vectored by the wheat curl mite, a microscopic arthropod. The mite lives and reproduces on wheat and other grass hosts. It survives the winter on seeded or volunteer winter wheat.
- c. The virus overwinters on volunteer wheat plants or on fall-seeded crops such as winter wheat. Conversely, the virus survives the summer months in infected spring seeded wheat.
- d. Typically spring wheat will express wheat streak mosaic early in the season from mid-May through June.
- e. Symptoms of wheat streak mosaic often appear at the edges of the field first. Infected plants are yellow and stunted, and almost no growth occurs
- f. Affected plants will develop yellow to white streaks on older leaves and light green streaks in young leaves.
- g. Stunting of the wheat plants can also be observed
- h. Diseased plants often don't produce heads; if heads are produced they are often sterile and do not produce seed.

#### 2. Distribution and Importance

- a. WSMV is present throughout the wheat production areas and affects spring and winter wheats. Is a more generally significant concern in winter wheat areas.
- b. In spring wheats, early infection may lead to a management decision for stand destruction. Growers need an insurance release prior to stand destruction.
- c. Wheat streak mosaic virus (WSM) causes severe yield losses on wheat some years.
- d. 2% yield loss in Kansas, estimate would be higher in Nebraska (2-5% average annual losses). This is an average of years where don't see any to years where it is a problem.
- e. A primary source of a green bridge to harbor the vector of the disease is volunteer wheat seedlings. These seedlings are common, especially following hail damage to standing wheat.

#### 3. Cultural Control of the wheat curl mite

- a. The most important point in managing wheat streak mosaic in the spring wheat areas is destroying volunteer winter wheat. A green bridge, living plants that can support the wheat curl mite that spreads the virus, are critical to the proliferation of the virus.
- b. Destruction of all volunteer wheat in fields before planting winter wheat is also recommended; volunteers act as a reservoir for the wheat curl mite.
- c. Winter wheat should not be planted too early; planting early of winter wheat correlates to increased chance of infestation by the mite.

#### 4. Non-Chemical Control

- a. Resistance to the virus is present to varying degrees in the cultivars grown in the Northern Great Plains Area
- b. Choosing varieties with increased resistance is a key management practice

#### 5. Pesticides

- a. Mite control to control the spread of the disease is not practical at this time.

6. Pipeline Products: Not applicable.
7. “To Do” List from mites
  - a. Research
    - a. Stronger resistance sources need to be incorporated into agronomically competitive cultivars
    - b. Research on mite movement and its relation to virus spread
    - c. Resistance reactions in spring wheats need to be identified
  - b. Education/Extension
    - a. Risk Management insurance decisions (Federal Crop Insurance) – crop destruction issues when the crop is infested need to be discussed
  - c. Regulatory: None

**Barley yellow dwarf (Barley yellow dwarf luteovirus- BYDV)**

1. Life Cycle
  - a. BYD, as a virus disease must survive in a living host or a vector to overwinter.
  - b. BYD, unlike WSMV, is vectored by an aphid. The bird cherry-oat aphid is considered the most important vector of BYDV in South Dakota.
  - c. Yellow dwarf will typically express on spring wheat in South Dakota as the crop is approaching the boot stage, from about June 1 to July 7.
  - d. Affected plants will have yellow leaf tips. Depending on the spring wheat cultivar, leaf tips may develop a reddish tinge, but yellow is most common.
  - e. If infection occurs early, such as may occur with late seeded wheat, stunting may occur.
  - f. The virus overwinters in southern reservoir hosts, blowing into the state each year with the aphid migration. Local reservoirs of BYDV are insignificant...
2. Distribution and Importance
  - a. BYD is present throughout the wheat production areas and affects spring and winter wheats.
3. Cultural Control
  - a. Yellow dwarf is best managed by planting early to avoid infection at the time when the crop is most susceptible to severe loss. With earlier planting, the crop will be at a later stage of development when and if aphids appear and infection occurs.
4. Non-Chemical Control
  - a. Resistance to the virus is present to varying degrees in the cultivars grown in the Northern Great Plains area, but is not generally exploited as a management technique.
5. Pesticides
  - a. Aphid control to limit the spread of the disease is not practical at this time.
6. Pipeline Products: Not applicable.
7. “To Do” List
  - d. Research: None
  - e. Education/Extension: None
  - f. Regulatory: None

## **Bacterial black chaff (*Xanthomonas campestris* pv. *translucens*)**

1. Life Cycle
  - a. The black chaff bacterium survives on a crop residue
  - b. The disease may be more severe in rainy years with high humidity or under overhead irrigation.
  - c. Bacterial black chaff of wheat will usually appear following flowering, about mid-June to mid-July for spring wheat in South Dakota
  - d. Large, dark brown to black spots may appear on the glumes or black bands may appear on the awns. The spots on the glumes may form streaks that run vertically.
  - e. The black chaff bacterium may also infect leaves, causing large, dark, greasy spots.
  - f. When black chaff infection occurs late, little damage results. Earlier infection can cause black point on the grain and the viability of the seed may be reduced.
2. Distribution and Importance
  - a. Bacterial black chaff is endemic to wheat production areas; however, annual losses are generally considered non-significant.
3. Cultural Control
  - a. The black chaff bacterium survives on a crop residue and may infect most small grains, so management of black chaff is through rotation to non cereal crops.
  - b. The disease may be more severe in rainy years with high humidity or under overhead irrigation. Avoiding late irrigation may reduce the severity of the disease.
4. Non-Chemical Control
  - a. Resistance is not known.
5. Pesticides
  - a. None
6. Pipeline Products: Not applicable
7. "To Do" List
  - g. Research: None
  - h. Education/Extension: None
  - i. Regulatory: None

## **IX. Insect Pests and Control Measures**

Several insect pests can occasionally become significant in South Dakota. Among the insects attacking wheat in the state are: aphids/greenbugs, grasshoppers, army cutworm and Hessian fly. Additionally, wheat stem sawfly, wheat stem maggot, pale western cutworm, true armyworm, wheat curl mite and orange wheat blossom midge are occasional pests. Fortunately, infestation of these pests to economic thresholds is not a common occurrence.

Starting in 1996 the wheat midge became a significant insect pest in North Dakota and had a significant influence on insecticide usage. Approximately 500,000 acres were treated with chlorpyrifos, the only registered insecticide for wheat midge. Other products used in North Dakota wheat were lambda cyhalothrin, carbofuran, carbaryl, and ethyl parathion. The most frequent target pests for these products included grasshoppers and cereal aphids. A total of 541,500 acres were estimated to have been treated with insecticides in 1996 (Zollinger, et al,

1998). In the absence of a wide spread insect outbreak, insecticide treatments are much lower in North Dakota, such as the 100,00 acres estimated to have been treated with insecticides in 2000 (Glogoza, et al., 2000).

There are no insect pests that damage wheat across the entire state of Nebraska. The most serious problems are sporadic and limited to certain regions of the state. The most serious arthropod pest in the state is the wheat curl mite, which transmits two virus diseases to wheat, wheat streak mosaic virus and high plains virus. The most serious insect pest in western Nebraska is the Russian wheat aphid followed by the army and pale western cutworms. The most serious wheat insect problems in eastern Nebraska are the greenbug and the Hessian fly. Because of the narrow profit margins found in dryland wheat production, growers try to minimize the inputs involved for management of insect problems. As a result, they rely on resistant varieties where available and on corrective measures of control. However, the low profit margins and risk involved in wheat production make growers hesitant to treat wheat with costly insecticides.

#### References Cited

- Glogoza, P., M. McMullen, R. Zollinger, , A. Thostenson, T. DeJong, W. Meyer, N. Schauer, J. Olson. 2002. Pesticide Use and Pest Management Practices for Major Crops in North Dakota 2000. NDSU Extension Rpt. No. 79.
- Zollinger, R. K., A. G. Dexter, G. K. Dahl, S. A. Fitterer, M. P. McMullen, G. E. Waldhaus, P. Glogoza, K. Ignaszewski. Pesticide Use and Pest Management Practices for Major Crops in North Dakota 1996. 1998. NDSU Extension Rpt. No. 43.

#### Wheat curl mite (WCM)

1. Distribution, Damage and Importance
  - a. The WCM transmits two viruses to wheat, the wheat streak mosaic and High Plains viruses. This virus complex is perhaps the most serious disease problem for growers in the western portions of the region and other areas of low rainfall. In winter wheat situations, severe damage follows hail storms due to increased volunteer plants. In spring wheats, volunteer winter wheat is a major source of mites.
  - b. Primarily a problem in winter wheat. A green bridge (corn and other alternate grass hosts) is needed to overwinter in the southern part of region and overwinter in the northern part of region.
  - c. Damage from these viruses is also noted in the other Northern Great Plains states.
  - d. Infestations from mites alone rarely result in economic damage in NE, but in the presence of virus, damage can be significant. Wheat Streak Mosaic Virus (WSMV) losses, although sporadic, can be significant.
  - e. Potential 100% loss. Loss increases significantly the earlier the infestation.
  - f. Wind movement of the mites is important in localized spread.
2. Cultural and non-chemical control
  - a. The mite is managed by cultural practices, primarily with controlling volunteer cereal grains and delaying planting date, a one week difference in emergence date

- can make a big difference.
- b. An infested spring wheat field provides the mite with a summer host, and eliminating this source reduces the mites' ability to over-summer and infest wheat in the fall.
- c. Planting spring wheat in close proximity to winter wheat crops provides the mite with a continuous green bridge.
- d. Delayed fall planting of winter wheat can reduce heavy fall infestations by the mite.
- e. It is mandatory in hail streaks for volunteer grain to be controlled.
- 3. Pesticides
  - a. Effective chemical control is very limited with Furadan 4F applied at planting the only effective method (from SLN for Nebraska). This is very expensive, especially considering the sporadic nature of the problem.
  - b. No miticide application for mite control is generally recommended.
  - c. Use of Roundup to control volunteers is very important.
- 4. Pipeline Products: None listed
- 5. "To Do" List
  - a. Research
    - i. Breed-in varietal resistance needed, both to mites and virus
    - ii. Need to understand transmission process of the virus
    - iii. Investigate the possibility of future seed treatments
    - iv. Identify economic thresholds, improve monitoring methods and prediction models for mites
    - v. Further identify movement and dynamics of mites
    - vi. Alternatives to glyphosate are needed to adequately control volunteer wheat
  - b. Education/Research
    - i. Education for producers to understand that when symptoms are seen, it is too late to control mites
    - ii. Education on rotational aspects of controlling volunteers and alternate mite hosts
    - iii. Education for economic thresholds, improved monitoring methods and prediction models for mites thresholds
    - iv. On-going education of controlling volunteer crops across wide areas
  - c. Regulatory
    - i. Roundup Ready wheat relationship – look at volunteer wheat control problems and alternative chemicals.

**Aphids:** Greenbug (*Schizaphis graminum*), English grain aphid (*Sitobion avenae*), Bird cherry oat aphid (*Rhopalosiphum padi*), and Russian wheat aphid (*Diuraphis noxia*).

1. Distribution, Damage and Importance
  - a. The English grain aphid, bird cherry oat aphid, and the greenbug are the most common aphid pests of small grains in the eastern part of the region. All aphids feed on plant sap, potentially affecting yield and grain quality.

- b. The Russian wheat aphid is known only as a minor pest in SD and ND. Russian wheat aphid is a more serious pest in the western part of the winter wheat production areas
  - c. The greenbug and the Russian wheat aphid are considered to be the most injurious of the aphids.
    - i. During feeding the greenbug injects saliva which is toxic to the plant causing yellowing and death of leaf tissue.
    - ii. The Russian wheat aphid impacts the plant by feeding on the sap, curling the leaves and causing yield losses. It does not transfer virus.
  - d. Large populations of bird cherry oat aphid are often associated with high infection levels of Barley yellow dwarf virus.
  - e. Problems with cereal aphids are dependent on when they migrate into the region, weather conditions when they arrive, and growth stage of wheat when populations increase. Aphids are present in wheat fields each season.
  - f. Late seeded crops are likely to be most severely infested in spring seeded and early seeded crops in winter wheat areas.
2. Cultural and non-chemical control
- a. Most infestations are minor and are kept in check by natural enemies such as syrphid fly larvae, aphid lions, ladybird beetles, several parasitic wasps, and parasitic fungi. When natural enemies are present in large numbers, farmers are discouraged from spraying insecticides.
  - b. Late seeded crops are likely to be most severely infested in spring seeded and early seeded crops in winter wheat areas.
3. Pesticides
- a. Thresholds in ND for English Grain Aphid, Bird Cherry Oat Aphid and Greenbug are 85% of stems with at least one aphid prior to complete heading.
  - b. Russian wheat aphid threshold in ND spring wheat is at 15-20% of tillers infested with at least one aphid up to flowering and 20%+ from flowering to early milk. It must be noted that Russian Wheat Aphid is far less common in spring wheat and durum growing areas.
4. Pipeline Products
5. "To Do" List
- a. Research
    - i. Varieties resistant to the aphid damage may be a potential.
    - ii. Potential for seed treatments for aphid control
    - iii. Existing thresholds need to be modified for economics and timing, cost of product and price of grain
    - iv. A resistant biotype of the Russian wheat aphid is known. Research into occurrence and how it will affect management is needed.
    - v. Relationships between natural enemies and aphids and potential pesticide treatments.
    - vi. Identify natural enemies and evaluation of released natural enemies
    - vii. Temperature requirements for optimal insecticide activity
    - viii. Minimum gallons needed for thorough coverage
    - ix. Investigate seed treatments, the economics of aphid control and possible new pesticide chemistries

- b. Education/Extension
  - i. Proper decision making for economic thresholds
  - ii. Education on when to scout, proper procedures, timing of scouting and keys for identification
- c. Regulatory: None

## **Pesticide Products for Aphid Control**

1. Organophosphates
  - a. Chlorpyrifos (Lorsban) at ½- 1 pt/A
    - i. PHI 28 d
    - ii. REI 24 h
    - iii. Efficacy – excellent
    - iv. Most commonly used insecticide for aphids at the lower rate
    - v. Minimum carrier of 2 gpa by air or 10 gpa by ground
    - vi. Maximum of two applications per crop
    - vii. No grazing/forage for 14 d
    - viii. No straw for 28 d
  - b. Ethyl Parathion (various)
    - i. All uses ended October 31, 2003
  - c. Malathion as Malathion 57EC at 1.5- 2 pt/A
    - i. PHI 7 d
    - ii. REI 12 h
    - iii. Efficacy – unknown due to low use
    - iv. Rarely used – better products available
    - v. Do no apply below 60°F
  - d. Methyl Parathion (As Methyl Parathion 8EC at 8 fl oz/A or Penncap-M at 2-3 pts/A)
    - i. PHI 15 d
    - ii. REI 48 hr
    - iii. Efficacy – good to excellent
    - iv. Used more in Penncap-M formulation
    - v. Avoid applying Penncap-M during pollen shed if bees will be present during foraging hours
  - e. Dimethoate (Cygon 400 or Dimethoate 400) at .5-.75 pt/A
    - i. PHI 35 d (Cygon 400), 60 d (Dimethoate 400)
    - ii. REI 48 h. Do not enter until spray has dried
    - iii. Efficacy – good to excellent, not as good on Russian Wheat Aphid when compared to chlorpyrifos
    - iv. Moderate use
    - v. Most cost effective at the low rate in areas where Russian wheat aphid is not a concern
    - vi. Used generally at the low rate
    - vii. Do not apply within 14 d of grazing immature wheat
  - f. Disulfoton (Di-Syston) at 0.5-1 pt/a



- i. PHI 30 d
    - ii. REI 48 h (or 72 h if less than 25 in rain per year)
    - iii. Efficacy – excellent for greenbug and others except Russian wheat aphid
    - iv. systemic
    - v. Rarely used due to toxicity
  - g. Methomyl (Lannate LV) at 12-24 fl oz/a
    - i. PHI 7 d
    - ii. REI 1 d
    - iii. Efficacy – not known due to low use
    - iv. Not used, expensive and limited supplies available
    - v. Do not feed treated forage within 10 d of application
  - h. Seed treatments: imidacloprid (Gaucho) and thiamethoxam (Cruiser)
    - i. Timing of use is a factor, early established fields are treated, high risk situations in winter wheat are potential targets
    - ii. Not used much currently in spring wheat
  - i. Planting time use: carbofuran (Furadan)
    - i. At planting, Special Local Needs (24c) label
- 2. Pyrethroids
  - a. zeta-cypermethrin (Mustang)
    - i. Efficacy – fair to good, especially when compared to traditional organophosphates
    - ii. Concern with resistance, population resurgence and effect on natural enemies
  - b. lambda-cyhalothrin (Warrior)
    - i. Efficacy – fair to good, especially when compared to traditional organophosphates
    - ii. Concern with resistance, population resurgence and effect on natural enemies

### **Orange Wheat blossom Midge: *Sitodiplosis mosellana***

1. Distribution, Damage and Importance
  - a. In recent years the orange wheat blossom midge has been a cause of economic concern in North Dakota and northwest Minnesota. In North Dakota the wheat midge has been detected in all counties north and east of the Missouri River. Significant damage has also been reported in Minnesota and the prairie provinces of Canada. This pest has not been a significant pest in South Dakota and Nebraska and Montana.
  - b. Infestations are difficult to detect. Damage is expressed after wheat is harvested.
  - c. The wheat plant is only attractive to the wheat midge from the time the head emerges from the boot to flowering. At this time female adults lay their eggs within the wheat head.
  - d. After hatching the midge larvae feed on the developing wheat kernels causing them to shrivel and become deformed. Only by examining the kernels can damage be found.
  - e. The wheat growing areas of Northeast and North Central North Dakota have been the

areas most heavily damaged. Yield and quality losses can range from 10-100% in spring planted wheats. However, other regions of the state have had populations of wheat midge which warranted control.

- f. Midge emergence can be predicted based on Growing Degree Day measurement with a 40°F threshold.
2. Cultural and non-chemical control
  - a. Wheat midge populations have been partially held in check by a parasitic wasp called *Macroglanes penetrans* (Kirby). This wasp can control up to 50% of the overwintering midge population each year.
  - b. Rotating wheat with other non susceptible crops aids in reducing wheat midge numbers. Crops such as oilseeds, barley, and oats can be grown with little or no risk of damage.
  - c. By selecting early maturing varieties and planting early, the wheat crop will head and flower before the peak of the wheat midge emergence.
  - d. Key Growing Degree Day measurements (40 DD base) for control are (from North Dakota):
    - i. Spring wheat planted before 200DD will head before midge emergence
    - ii. Spring wheat planted from 200-600 DD will be heading at midge emergence and are of concern for monitoring
    - iii. Spring Wheat planted after 600 DD will head after peak midge emergence.
3. Pesticides
  - a. Current treatment recommendations are when one or more midge are observed for every four to five wheat heads for hard red spring wheat, and one or more midge for every seven wheat heads for durum wheat.
  - b. Treat only when 75% of wheat heads have emerged from the boot.
  - c. Treatment after 50% of the wheat heads have flowered is not recommended because of reduced insecticidal efficacy and for the protection of the parasitic wasps.
4. Pipeline Products: None listed
5. “To Do” List
  - a. Research
    - i. Tolerance or resistance in spring and durum varieties.
    - ii. Detection tools, prediction models for midge outbreaks
  - b. Education/Extension
    - i. Education on current detection tools and prediction model results
    - ii. Overwintering population surveys for risk assessment
  - c. Regulatory: None

### **Pesticides for Use Against Orange Wheat Blossom Midge**

1. Organophosphates
  - a. Chlorpyrifos (Lorsban) at 1 pt/A
    - i. PHI 28 d
    - ii. REI 24 h
    - iii. Efficacy – good to excellent
    - iv. Widely used where infestation potential is high, often used in combination with fungicides for scab management

- v. Minimum carrier of 2 gpa by air or 10 gpa by ground
- vi. Maximum of two applications per crop
- vii. No grazing/forage for 14 d
- viii. No straw for 28 d
- ix. Treat when 75% of wheat heads have emerged
- x. Apply product in late afternoon.
- b. Methyl Parathion (As Penncap-M at 2-3 pts/A)
  - i. PHI 15 d
  - ii. REI 48 hr
  - iii. Efficacy – fair to good, works in small trials
  - iv. Not used as much as Lorsban, information is not as readily available on efficacy
  - v. Avoid applying Penncap-M during pollen shed if bees will be present during foraging hours.
  - vi. Fields must be posted in North Dakota

**Grasshoppers:** Clearwinged grasshopper (*Camnula pellucida*), Two-striped grasshopper (*Melanoplus bivittatus*), Migratory grasshopper (*Melanoplus sanguinipes*), differential grasshopper (*Melanoplus differentialis*), and Redlegged grasshopper (*Melanoplus femurrubrum*).

#### 1. Distribution, Damage and Importance

- a. Grasshoppers are sporadic pests across the Northern Great Plains especially in regions that receive little rainfall. Some areas have a continuous problem with grasshoppers.
- b. Weather is one of the main factors affecting grasshopper populations. Outbreaks are usually preceded by several years of hot, dry summers and warm falls, which allow populations to increase.
- c. Damage to wheat is usually concentrated near field margins. Individual plants can be damaged by leaf stripping, awn loss, head clipping, and damaged kernels.
- d. Winter wheat - biggest problem can occur when wheat is emerging and adult grasshoppers infest seedlings.
- e. Grasshoppers can migrate in from surrounding areas and long distance migrations are also possible.

#### 2. Cultural and non-chemical control

- a. Natural enemies include parasites, predators, and diseases. Some type of natural enemy attacks all grasshopper stages.
- b. Cool, moist weather can help reduce grasshopper populations by increasing the incidence of naturally-occurring pathogenic fungal diseases of grasshoppers.
- c. Early seeding (spring wheat) establishes vigorously growing plants that are more tolerant to grasshopper injury. Early seeded crops (spring wheat) will mature earlier and reduce the risk of late season migrations of adult grasshoppers. Late planting in the fall will reduce risk of injury.
- d. Crop rotation, trap strips, and timely harvesting crops are other cultural control practices used to reduce grasshopper damage.

- e. Avoid planting wheat into areas of high risk, such as areas with green plant cover (mixed vegetative growth).
  - f. Height of border area determines how far out grasshoppers will migrate into the field.
3. Pesticides
- a. Grasshoppers are more easily controlled in the nymphal stage.
  - b. For spring grasshopper hatch, treatment is advised when 30+ nymphs per square yard are found in field margins, or 20+ nymphs per square yard are found within the field. For fall seeded wheat, treatment is directed at adult grasshoppers when populations exceed 15+ adults per square yard in field borders.
4. Pipeline Products: diflubenzuron, fipronil
5. “To Do” List
- a. Research
    - i. Economic thresholds need to be worked on and standardized, if possible
    - ii. Seed treatments need to be looked at for grasshopper control
    - iii. Bait vs. contact efficacy, ground vs. aerial pesticide application, effectiveness of border treatment vs. whole field treatment, strip applications, importance of non-crop areas and control in those areas
    - iv. Movement patterns of grasshoppers
  - b. Education/Extension
    - i. Monitoring methods and prediction models need further investigation and education
  - c. Regulatory
    - i. Seed treatments labeled for grasshopper control

### **Pesticides for Use Against Grasshoppers**

- 1. Organophosphates
  - a. Chlorpyrifos (Lorsban 4E) at ½- 1 pt/A
    - i. PHI 28 d
    - ii. REI 24 h
    - iii. Efficacy – fair to good
    - iv. Used widely for grasshopper control
    - v. Minimum carrier of 2 gpa by air or 10 gpa by ground
    - vi. Maximum of two applications per crop
    - vii. No grazing/forage for 14 d
    - viii. No straw for 28 d
  - b. Ethyl Parathion (Ethyl Parathion 8EC)
    - i. All uses ended October 31, 2003
  - c. Malathion (Malathion 57EC) at 1.5- 2 pt/A
    - i. PHI 7 d
    - ii. Efficacy – unknown, not used enough
    - iii. Hardly used, better alternatives
    - iv. Do no apply below 60°F
    - v. No grazing restrictions
  - d. Methyl Parathion (As Methyl Parathion 8EC at 8 fl oz/A or Penncap-M at 2-3 pts/A)

- i. PHI 15 d
    - ii. REI 48 hr
    - iii. Not used widely for grasshoppers
    - iv. Avoid applying PennCap-M during pollen shed if bees will be present during foraging hours
  - e. Dimethoate (Cygon 400 or Dimethoate 400) at .75 pt/A
    - i. PHI 35 d (Cygon 400), 60 d (Dimethoate 400)
    - ii. REI 48 h Do not enter until spray has dried
    - iii. Efficacy – good, not as good as Lorsban
    - iv. Used, but not as much as Lorsban
    - v. Do not apply within 14 d of grazing immature wheat
  - f. Phorate (Thimet 20G) at 1.2 oz/1000 ft row with minimum of 8 in rows
    - i. PHI: Planting time use only
    - ii. Efficacy – good if rainfall
    - iii. Not used much anymore due to odor and other risks
    - iv. Specialized application method which isn't widely available
    - v. Use on winter wheat in-furrow only
    - vi. Do not graze within 45 days of treatment
- 2. Carbamates
  - a. Carbaryl (Sevin) at 0.5-1.5 lb ai/A (rate of actual product will vary)
    - i. PHI 21d grain or straw, 7 days grazing or forage
    - ii. REI 12 h
    - iii. Efficacy – fair to good, depending on stage being controlled
    - iv. Several formulations available, including a bait
    - v. First choice of USDA for border areas
    - vi. Use higher rates for adult control
    - vii. Two applications per season maximum
    - viii. Maximum of 3 quarts per acre
    - ix. Current labels do not list grasshoppers on pest list for wheat crops
  - b. Carbofuran (Furadan 4F) at 0.25-0.5 pt/A
    - i. PHI not listed, but application limited to pre-heading
    - ii. REI 48 h
    - iii. Efficacy – excellent
    - iv. Not used much due to limitation to use prior to heading, also at planting
    - v. Two application per season maximum
    - vi. Do not feed treated forage to livestock
    - vii. Minimum carrier of 2 gallons by air or 10 gallons by ground
    - viii. Do not apply on fields in proximity to waterfowl nesting areas and/or on fields where waterfowl are known to repeatedly feed
- 3. Pyrethroids
  - a. Lambda cyhalothrin (Warrior T) at 2.56-3.84 fl oz/A
    - i. PHI 30 d
    - ii. REI 24 h
    - iii. Efficacy – good to excellent
    - iv. Widely used in wheat and non-crop areas (24C)
    - v. Forage can not be fed to livestock

- vi. When applied by air, minimum carrier is 2 GPA
  - vii. Available for use as a 24(c) label in SD and ND for use on wheat borders in non-crop areas.
- b. Zeta cypermethrin (Mustang Max) at 3.2-4.0 oz/A
- i. PHI 14 d
  - ii. REI 12 h
  - iii. Efficacy – good to excellent
  - iv. New registration this season (2003) so use pattern not known yet
  - v. Do not make applications less than 14 d apart
  - vi. Maximum of .125 lb AI/A per season
  - vii. Apply in a minimum of 2 GPA by air or 10 GPA by ground

**Armyworms: *Pseudaletia unipuncta***

1. Distribution, Damage and Importance
  - a. Outbreaks in northern wheat production areas occur when large migrations of moths from the south occur in late spring and early summer.
  - b. Moths lay eggs in moist, shady areas where small grains have lodged or been damaged by hail or wind.
  - c. Armyworms feed at night on above ground vegetation, and hide under the foliage and in the soil during the day.
  - d. In most years, populations are kept low by unfavorable weather conditions such as cool wet weather.
2. Cultural and non-chemical control
  - a. A number of diseases and parasites attack armyworms. Tachinid flies, parasitic wasps, and viruses are all natural controls of the armyworm. These natural enemies often do not destroy armyworm larvae until after severe crop damage has occurred. Their greatest impact is preventing unacceptable increases in the next generation.
3. Pesticides
  - a. Current treatment recommendations are when four to five or more worms per square foot are present.
  - b. If armyworms are migrating, treat ahead of the infestation to create a barrier strip to prevent movement.
4. Pipeline Products: None listed
5. “To Do” List
  - a. Research: None
  - b. Education/Research: None
  - c. Regulatory: None

## Pesticides for Use Against Armyworms

1. Organophosphates
  - a. Chlorpyrifos (Lorsban 4E) at 1 pt/A
    - i. PHI 28 d
    - ii. REI 24 h
    - iii. Minimum carrier of 2 gpa by air or 10 gpa by ground
    - iv. Maximum of two applications per crop
    - v. No grazing/forage for 14 d
    - vi. No straw for 28 d
    - vii. Control reduced if >80°F, dry conditions or larvae greater than ½ in long
  - b. Ethyl Parathion (Ethyl Parathion 8EC)
    - i. All uses ended October 31, 2003
  - c. Malathion (Malathion 57EC) at 1.5- 2 pt/A
    - i. PHI 7 d
    - ii. REI 12 h
    - iii. Do no apply below 60°F
    - iv. No grazing restrictions
  - d. Methyl Parathion (As Methyl Parathion 8EC at 8 fl oz/A or Penncap-M at 2-3 pts/A)
    - i. PHI 15 d
    - ii. REI 48 hr
    - iii. Methyl parathion 8EC is aerial application only
    - iv. Avoid applying Penncap-M during pollen shed if bees will be present during foraging hours
  - e. Methomyl (Lannate LV) at 12-24 fl oz/a
    - i. PHI 7 d
    - ii. REI 1 d
    - iii. Don not feed treated forage within 10 d of application
2. Carbamates
  - a. Carbaryl (Sevin) at 1-1.5 lb ai/A (rate of actual product will vary)
    - i. PHI 21d grain or straw, 7 days grazing or forage
    - ii. REI 12 h
    - iii. Two applications per season after the boot stage
    - iv. Maximum of 3 quarts per acre
3. Pyrethroids
  - a. Lambda cyhalothrin (Warrior T) at 2.56-3.84 fl oz/A
    - viii. PHI 30 d
    - ix. REI 24 h
    - x. When applied by air, minimum carrier is 2 GPA
  - c. Zeta cypermethrin (Mustang Max) at 1.76-4.0 oz/A
    - i. PHI 14 d
    - ii. REI 12 h
    - iii. Do not make applications less than 14 d apart
    - iv. Maximum of .125 lb AI/A per season
    - v. Apply in a minimum of 2 GPA by air or 10 GPA by ground

4. Other
  - a. Spinosad (Tracer) at 1-3 fl oz/A
    - i. PHI 21 d grain or straw, 14 d forage or hay
    - ii. REI 4 h
    - iii. Maximum of 9 oz/A per year

**Cutworms:** (Lepidoptera: Noctuidae) Army Cutworm (*Euxoa auxiliaries*), Dingy cutworm (*Fletia jaculifera*), Red-backed cutworm (*Euxoa ochregaster*), pale western

1. Distribution, Damage and Importance
  - a. In western part of the region, the pale western and the army cutworms are important pests of small grains.
  - b. Pale western cutworm eggs hatch in the spring, and the larvae feed below ground, cutting plants below ground level.
  - c. Army cutworm eggs hatch in the fall, larval feeding is above ground.
  - d. The dingy cutworm and red-backed are common but wheat is not as frequently affected as the regions field crops.
2. Cultural and non-chemical control
3. Pipeline Products: None listed
4. “To Do” List
  - a. Research
    - i. Low temperature thresholds for insecticides
    - ii. Develop economic thresholds and especially prediction models
    - iii. Investigate why cutworms are becoming a bigger problem
  - b. Education/Extension
    - i. Web site development for tracking, predictions and control options
    - ii. Deliver prediction models to growers
  - c. Regulatory: None

### **Pesticides for Use Against Cutworms**

1. Organophosphates
  - a. Chlorpyrifos (Lorsban 4E) at 1 pt/A
    - i. PHI 28 d
    - ii. REI 24 h
    - iii. Efficacy – good
    - iv. Not as good as the pyrethroids, not as widely used due to this
    - v. Minimum carrier of 2 gpa by air or 10 gpa by ground
    - vi. Maximum of two applications per crop
    - vii. No grazing/forage for 14 d
    - viii. No straw for 28 d
4. Pyrethroids
  - a. Lambda cyhalothrin (Warrior T) at 2.56-3.84 fl oz/A



- i. PHI 30 d
  - ii. REI 24 h
  - iii. Efficacy – excellent
  - iv. Product of choice
  - v. Good temperature relationships, more effective under cool temps
  - vi. When applied by air, minimum carrier is 2 GPA
- b. Zeta cypermethrin (Mustang Max) at 1.76-4.0 oz/A
  - i. PHI 14 d
  - ii. REI 12 h
  - iii. Efficacy – excellent
  - iv. New product, not as widely used yet
  - v. Should be similar to Warrior
  - vi. Do not make applications less than 14 d apart
  - vii. Maximum of .125 lb AI/A per season
  - viii. Apply in a minimum of 2 GPA by air or 10 GPA by ground

**Wireworms:** (Coleoptera: Elateridae)

1. Distribution, Damage and Importance
  - a. Wireworms are a minor pest of spring and durum wheats in North Dakota and across the Northern Great Plains.
  - b. The wireworms or click beetle larvae live for two-nine years in the soil. They are attracted to carbon dioxide, which is released by germinating seeds and growing plant tissue.
  - c. Wireworms feed on the seeds and roots. Damaged plants are then more susceptible to plant pathogens.
2. Cultural and non-chemical control
3. Pesticides
  - a. The most common insecticide registered for wireworm control is lindane. Lindane is applied to the seed just before planting. Lindane can be purchased as a dry drill box treatment or as a liquid formulation.
4. Pipeline Products: None listed
5. “To Do” List
  - a. Research: None
  - b. Education/Research: None
  - c. Regulatory: None

**Pesticides for Use Against Wireworms**

1. Lindane at 2 oz/100 lb seed (Lindane) or 2 oz/bu (Maneb-Lindane)
  - a. REI 12 h (Lindane) or 24 h (Maneb-Lindane)
  - b. Do not use treated seed for feed.
2. Imidacloprid (Gaucho) Seed treatment.
3. Thiamethoxam (Cruiser) at 0.75-1.33 fl oz/100 lb seed

- a. REI 12 h

### **Cereal Leaf Beetle: (*Oulema melanopus*)**

1. Distribution, Damage and Importance
  - a. This is an imported insect pest from Europe.
  - b. The only reports in the region covered by this strategic plan have been from two western North Dakota counties, Williams and McKenzie.
  - c. This pest is a serious pest of wheat and barley production in Montana.
  - d. Damage is from foliar feeding by adults and larvae. The larvae are the most damaging stage, and pesticide treatments target this growth stage.
  - e. Generally newer plant tissue is favored by the insect
  - f. Damage is expressed as elongated slits in leaves from foliar feeding.
2. Cultural and non-chemical control
  - a. Careful scouting is required for effective management of this pest.
3. Pesticides
  - a. The first sign of infestation in the spring will be adult foliar feeding, but control measures are focused towards the larvae.
  - b. Eggs and larvae are monitored closely. Threshold values for treatment are based on egg and larval numbers per stem
  - c. Scouting involves looking at ten plants per location with at least one scouting location per 10 acres of crop.
  - d. Before boot stage, treatment thresholds are three eggs and larvae or more per plant (including all tillers).
  - e. Boot stage is a critical point in plant development, as damage to the flag leaf will result in decreased grain yield and quality. As a result, at boot stage, the treatment threshold drops to one larva or more per flag leaf.
4. Pipeline Products: None listed
5. "To Do" List
  - a. Research: None
  - b. Education/Research: None
  - c. Regulatory: None

### **Pesticides for Use Against Cereal Leaf Beetle**

1. Organophosphates
  - b. Malathion (Malathion 57EC) at 1- 2 pt/A
    - i. PHI 7 d
    - ii. Do not apply below 60°F
    - iii. No grazing restrictions
  - c. Malathion (Malathion ULV) at 4-8 oz/A
    - i. PHI 21 d grain or straw, 14 d forage or hay
  - d. Methomyl (Lannate LV) at 12-24 fl oz/a
    - i. PHI 10 d for grazing
    - ii. REI 1 d

- iii. Don not feed treated forage within 10 d of application
- 2. Carbamates
  - e. Carbaryl (Sevin XLR Plus, 4F, 4-Oil) at 2 pt/A or Sevin 80S at 1.25 pt/A
    - i. PHI 21d grain or straw, 7 days grazing or forage
    - ii. REI 12 h
    - iii. Two applications per season maximum
    - iv. Maximum of 3 quarts per acre
    - v. Current labels do not list grasshoppers on pest list for wheat crops
  - f. Carbofuran (Furadan 4F) at 0.5 pt/A
    - i. PHI not listed, but application limited to pre-heading
    - ii. REI 48 h
    - iii. Apply before heads emerge from boot
    - iv. Two application per season maximum
    - v. Do not feed treated forage to livestock
    - vi. Minimum carrier of 2 gallons by air or 10 gallons by ground
    - vii. Do not apply on fields in proximity to waterfowl nesting areas and/or on fields where waterfowl are known to repeatedly feed
- 3. Pyrethroids
  - g. Lambda cyhalothrin (Warrior T) at 2.56-3.84 fl oz/A
    - i. PHI 30 d
    - ii. REI 24 h
    - iii. When applied by air, minimum carrier is 2 GPA
    - iv. Do not apply more than 7.6 oz/A per season
  - h. Zeta cypermethrin (Mustang Max) at 3.2-4.0 oz/A
    - i. PHI 14 d
    - ii. REI 12 h
    - iii. Do not make applications less than 14 d apart
    - iv. Maximum of .125 lb AI/A per season
    - v. Apply in a minimum of 2 GPA by air or 10 GPA by ground
- 4. Other
  - a. Spinosad (Tracer) at 1-3 fl oz/A
    - i. PHI 21 d grain or straw, 14 d forage or hay
    - ii. REI 4 h
    - iii. Maximum of 9 oz/A per year

**Hessian Fly:** (*Mayetiola destructor*)

- 1. Distribution, Damage and Importance
  - a. Hessian fly overwinters as larvae (maggot) in winter wheat, volunteer grain and wheat stubble.
  - b. Overwintering maggots pupate in the spring and emerge as adults from April to May.
  - c. Adults lay eggs on new winter and spring wheat plants, the eggs hatch, and larvae

feed and pupate by June. Pupal stage Hessian flies are called “flaxseed” stage due to the similar appearance of the pupal case. Adults emerge in August and September to lay eggs for the overwintering stage.

2. Cultural and non-chemical control
  - a. Winter wheat planting date. Delaying planting of winter wheat will help reduce the infestation of the fall growth of the winter wheat.
  - b. Tillage. Reducing stubble and destroying volunteer grain helps to reduce overwintering stages of the pest.
  - c. Rotation to non-susceptible crops, such as oats, corn, soybean, sunflower, or flax will reduce populations.
  - d. Resistant varieties. Currently, two varieties of hard red spring wheat that were released with specific resistance to Hessian Fly are available. The varieties Guard and Shield are older varieties which carry Hessian Fly resistance, but do not meet agronomic performance standards of more modern varieties.
3. Pesticides
  - a. Thimet is registered for planting time control as an in-furrow treatment. Thimet is an organophosphate insecticide.
4. Pipeline Products: None listed
5. “To Do” List
  - a. Research: None
  - b. Education/Research: None
  - c. Regulatory: None

### **Wheat Stem Maggot**

1. Distribution, Damage and Importance
  - d. Damage is seen on plants after flowering and is caused when the maggot of the fly tunnels into and cuts the stem. Heads of infested plants turn white and can be easily pulled from the sheath
  - e. Infestations rarely result in economic damage (often less than 2%)
2. Cultural and non-chemical control
  - f. Crop rotation and destruction of volunteer grain through tillage or other means will reduce maggot populations.
3. Pesticides
  - d. No chemical control is recommended or available.
4. Pipeline Products: None available
5. “To Do” List
  - a. Research: None
  - b. Education/Research: None
  - c. Regulatory: None

## Wheat Stem Sawfly

1. Distribution, Damage and Importance
  - a. Larvae of the wheat stem sawfly overwinter in wheat stubble in the spring wheat growing areas.
  - b. Damage is more common in the Dakotas. Damage to the plant is caused by the larvae of the sawfly tunneling within the wheat stem.
  - c. Grain yield can be reduced 10-14% in heavy infestations, with additional loss occurring through lodging of the plants as the crop matures, resulting in harvest losses.
  - d. Infested stems can be seen by looking for a reddish-brown spot below the second or third node.
2. Cultural and non-chemical control
  - a. Swathing heavily infested fields when the grain is relatively green, but physiologically mature, will help reduce harvest losses from lodging. This tactic is recommended if over 6% of the stems in a field are infested.
  - b. Shallow fall tillage, which dislodges the stubble, but leaves most of the stubble on the ground surface, can reduce survival of overwintering larvae by as much as 90%. Tillage may further be limited to heavy infestation areas within a field if reduced tillage is generally practiced.
  - c. Rotation to non-host crops such as oats, flax, sunflower, legumes can be effective. Barley, rye, durum and winter wheat are less desirable hosts than hard red spring wheat.
  - d. Resistant varieties. Choosing varieties with a solid stem, rather than hollow, can be effective. Solid stem varieties are generally resistant to significant damage.
3. Pesticides
  - a. No chemical control is recommended or available.
4. Pipeline Products: None available
5. "To Do" List
  - a. Research: None
  - b. Education/Research: None
  - c. Regulatory: None

## **X. Weed Management in Northern Wheat**

Many different weed species attack wheat fields in South Dakota. Annual and perennial weeds are yearly concerns for growers in the state. Primary among the annual weeds causing greatest concern are the grasses green foxtail (*Setaria viridis*), yellow foxtail (*Setaria lutescens*) and wild oat (*Avena fatua*) and the broadleaves kochia (*Kochia scoparia*), wild buckwheat (*Polygonum convolvulus*), Russian thistle (*Salsola kali*), and wild mustard (*Brassica kaber*). Perennial broadleaves of concern include field bindweed (*Convolvulus arvensis*) and Canada thistle (*Cirsium arvense*). Many other species are present in producers' fields, but these represent the primary focus of pesticide applications.

The most problematic weeds in winter wheat are the winter annual grasses. Because of

their similarity in life cycle to wheat, they are capable of providing the greatest competition with wheat. In addition, their similarity to wheat limits the herbicide options that are effective against these grasses. The most serious winter annual grass weeds are jointed goatgrass, downy brome and volunteer rye. Management of these winter annual grass weeds relies mostly on cultural practices. Wheat competes well against annual, warm season broadleaves, but winter annual broadleaf weeds, such as field pennycress and blue mustard, can be very competitive. Reduced wheat canopy can result in significant warm season broadleaf weed problems. Management of these weed problems relies on good control of these weeds in the other crops in the rotation and in the fallow. Herbicides are effective at reducing these weed problems and are most commonly applied in the spring for weed control. Approximately 70% of Nebraska's winter wheat is treated with herbicides. Most of this is targeted at controlling the summer annual broad leaves, which are sprayed late in the fall or early in the spring. Broadleaf weeds that are problematic include Russian thistle, kochia, common sunflower, field pennycress and blue and tansy mustard. One problem developing in the region is ALS resistant kochia. These weeds are becoming much more difficult to control with ALS-inhibiting herbicides (sulfonylurea herbicides).

Weed control in small grains is generally required in North Dakota to achieve a profitable yield. Broadleaf weeds, foxtails and wild oat infest small grains statewide. The use of the proper cultural control techniques plus the use of chemical controls may be required to control troublesome weeds.

### **General Weed Management Practices**

- Using good cultural practices is a very important step in weed management. Always plant seed from weed free seed stocks, prevent weed growth and development, especially seed production and properly clean harvesting and tillage equipment to prevent spread of weed seed and plant parts. Good seeding practices lead to full, uniform stands.
- Field history data and planning are important in spring wheat management.
- Unpredictable weather and extremes frequently result in unanticipated weed problems and herbicide carryover.
- Special situations include:
  - **Delayed Planting.** Wet spring conditions that delay planting two weeks or more affects both crop and weeds. The crop may tiller less, be less competitive and yield expectations are reduced. Foxtail competition effects are increased. The application window for broadleaves is reduced; risk of crop injury is increased at advanced crop stages.
  - **Delayed harvest.** Straight-cut harvest (no use of windrows) has become the standard. Preharvest treatments are more important when rain/wet fields delay harvest. Foxtail and kochia are primary preharvest targets. Treatment for perennial weeds preharvest combines perennial weed control with usual postharvest burndown in no-till systems.
  - **Preplant burndown.** Planting is normally completed before weed emergence in no-till systems; seedbed tillage destroys the initial weed flush in conventional systems. Delayed seeding in no-till has increased the need for burndown. Currently wild oat can be controlled; wild buckwheat and kochia are not adequately controlled. Failure to provide early control results in improper weed/crop staging for postemerge herbicides. Failure to control emerged weeds at planting results in a reduced yield.
  - **Crop Rotation.** Crop rotation is an effective management tool, especially for

- breaking the cycle of winter annual grasses
- ***Crop Management.*** The use of quality seed and good seedbed preparation and seed placement to increase crop competition with weed is often overlooked in herbicide performance.
- Good weed management in winter wheat in Nebraska is important to obtaining optimum yields. Limited soil moisture rapidly creates yield-limiting competition with weed populations. However, a well-established wheat canopy provides very good competition against weeds. This is especially true in relation to spring germinating annual weed species.

### **Fallow weed control, Preplant burndown weed control and Post-Harvest weed and volunteer control**

- Glyphosate products (Roundup and many others) are the primary herbicide used during fallow periods, for burndown and post-harvest. It is often mixed with 2, 4-D or dicamba to increase efficiency on broadleaf weeds such as kochia and Russian thistle.
- Under dry, stressful conditions, paraquat (Gramoxone Max) may be substituted for glyphosate. Paraquat (Gramoxone Max) is combined with 2, 4-D Ester or dicamba products.
- Carfentrazone (Aim EW) is labeled for burndown and post-harvest weed control.
- Quinclorac (Paramount), a newer synthetic auxin herbicide may be used at 3-5.3 fl oz/A in fallow and preplant wheat (spring or winter).

### **Pesticide Resistance and Resistance Management**

Pesticide resistance has become a concern in recent years. Kochia resistant to herbicides that act on the plant enzyme ALS, including the sulfonylureas, has become prominent in much of the Northern Great Plains. Continued use of certain herbicide modes of action will undoubtedly result in further weed species demonstrating tolerance or resistance to the herbicides. Management to reduce herbicide resistance then becomes a priority. Significant research into resistance management has been done by the Weed Science Society of America (WSSA) and the Herbicide Resistance Advisory Committee (HRAC). Herbicides are now classified as to their potential for concern in resistance management.

### **Herbicide Resistant Weeds**

A number of weed biotype populations have been identified in the Northern Great Plains as having resistance to one or more herbicide classes. Those found as resistant to herbicides and the herbicide class are:

1. South Dakota
  - a. Kochia- ALS inhibitors
  - b. Common sunflower- ALS inhibitors
2. North Dakota
  - a. Kochia- ALS inhibitors, Triazines and Synthetic auxins
  - b. Green foxtail- Dinitranilines

- c. Wild oat- ACCase and ALS inhibitors
- d. Redroot pigweed- ALS inhibitors
- e. Wild mustard- ALS inhibitors
- f. Eastern black nightshade- ALS inhibitors
3. Nebraska
  - a. Shattercane- ALS inhibitors
  - b. Common waterhemp- Triazines
4. Minnesota
  - a. Lambsquarters- Triazines
  - b. Velvetleaf- Triazines
  - c. Redroot pigweed- Triazines
  - d. Wild oat- ACCase
  - e. Kochia- ALS inhibitors
  - f. Common cocklebur- ALS inhibitors
  - g. Giant foxtail- ALS inhibitors
  - h. Robust white foxtail- ALS inhibitors and ACCase
  - i. Yellow foxtail (lutescens)- ALS inhibitors
  - j. Common ragweed- ALS inhibitors
  - k. Purple robust foxtail- ACCase

*List above adapted from: Heap, I. The International Survey of Herbicide Resistant Weeds. Online. Internet. November 09, 2003. Available online at <http://www.weedscience.org>*

### **Resistance Management Strategies**

- 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, soybeans and wheat. This would include the triazines (translocated photosynthetic inhibitors) and the ALS inhibitors (sulfonylureas and imadazolinones).
- There is considerable concern about the potential development of resistance to glyphosate as it also has become widely used.
- More complex and more expensive approaches to weed control are often required to manage resistance. Since whole groups of compounds may lose effectiveness many individual products within those groups will no longer be efficacious. Producers need to use multiple modes of action to control weeds.
- Crop rotation (to permit rotation of herbicides) and herbicide combinations are often used in resistance management.
- Management must also consider tillage methods.
- 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.



## Herbicide Tolerant Wheat

Herbicide tolerant crop varieties have become a mainstay in soybean production in the Midwest and are becoming more common in corn production as well. Data from the National Agricultural Statistics Service showed that SD, NE and MN producers planted 91%, 86% and 79% of the soybean acreage to "biotechnology varieties" showing herbicide resistance. Of the corn acreage, 34%, 36% and 31% of the planted acreage in SD, NE and MN, respectively was herbicide resistant. These numbers, especially for SD, are significantly higher than the national average. Herbicide tolerant wheat is being researched at the current time. There are currently two classes of herbicide tolerant wheat being researched, Clearfield Wheat, developed originally by BASF and Roundup Ready Wheat, with technology from Monsanto. Widespread adoption of wheat varieties carrying these traits is an unknown factor to date, as the work is relatively new, but these varieties may play a role in pest management in future years.

### Clearfield Wheat

- System consists of herbicide-tolerant wheat and the use of Beyond herbicide.
- Beyond has the active ingredient imazamox, an imadazolinones product in the ALS inhibitor class of herbicides.
- Clearfield wheat was developed by BASF from an induced mutation in a French wheat cultivar. The herbicide-tolerant trait was introduced into adapted germplasm from the United States through Texas A & M University in 1996 and has expanded in research use since that time.
- Clearfield wheat is considered non-transgenic wheat because the product was developed using conventional plant breeding techniques.
- Beyond herbicide received EPA clearance for use in 2001.
- Stewardship requirements for Clearfield wheat include purchasing seed from a Clearfield seed dealer and significant penalties for use of bin-run seed.
- Stewardship Recommendations include
  - Don't plant Clearfield wheat more than two out of four years
  - Limit the reliance on ALS inhibitor herbicides through tank-mixes with multiple modes of action, as weed resistance risk is high with this class of herbicides.
  - Properly manage weeds in wheat-fallow-wheat rotations using non-ALS herbicides for burndown in the fallow years
  - For jointed goatgrass, treat entire fields with Beyond herbicide and control goatgrass in field border areas prior to goatgrass seed set to reduce outcrossing potential.

### Roundup Ready Spring Wheat

- Roundup Ready Wheat is currently under experimental development for Hard Red Spring Wheat production by several university and private wheat breeding programs in the United States and Canada. These breeding programs have entered into cooperative agreements with Monsanto to develop Roundup Ready spring wheats.
- Roundup Ready Wheat was developed by Monsanto by introducing the Roundup Ready trait into adapted cultivars to the primary growing areas. Roundup Ready crops have an alternate production mechanism within the plant cells for the EPSP enzyme system that is

the target site of glyphosate herbicides.

- Roundup ready wheat varieties are still experimental and will be released only when the following milestones have been achieved (from “Bringing New Technologies to Wheat. Information on the Development of Roundup Ready® Wheat” Monsanto, online):
  - The food, feed and environmental safety of Roundup Ready wheat is demonstrated, resulting in regulatory approvals in the United States, Canada and Japan.
  - Appropriate regulatory trade approvals, thresholds or marketing agreements are in place in major export markets.
  - Appropriate grain handling protocols and standardized sampling and detection methods are developed and implemented.
  - Comprehensive agronomic stewardship programs and best management practices are developed.
  - Varieties meet or exceed industry standards for grain end-use quality.
  - Buyers are identified who will procure and use wheat ingredients with biotech traits

## **Major Weed Pest Groups**

### **Annual Grasses**

**Foxtails:** Green foxtail (*Setaria viridis*), Yellow foxtails (*Setaria glauca*).

Commonly found in field crops across the Northern Great Plains, often called pigeongrass. Foxtails are one of the regions most serious and widespread annual weeds. Foxtails are most competitive when wheat is seeded late and soil temperatures are warm which promotes foxtail germination and growth. Yellow foxtail is a more difficult weed to control than green foxtail.

Tillage is one of the best strategies for reducing foxtail infestations. Infestations with less than 30 plants per square foot, and foxtails emerging into a crop at the three to four-leaf stage, generally do not require control. At these levels of infestation the crop can usually out-compete foxtail. Heavy infestations with more than 100 plants per square foot require chemical control.

**Wild Oat:** (*Avena fatua*)

Wild oat is a cool season annual, one to four feet tall. It is native to Europe but is common throughout much of western North America, including all of the Dakotas. Wild oat is one of the most serious weed problems in small grains. It is difficult to eradicate because the plants drop their seed prior to the crop being harvested. Seed dormancy results in delayed germination.

Delaying seeding is one of the most practical methods of culturally controlling wild oats. Harrowing emerging wild oats following crop seeding may also be effective in reducing wild oat populations before the crop emerges. Pre-emerge herbicides applied in the fall or spring prior to seeding can provide effective wild oat control. Post-emerge herbicides are also widely available and can be very effective.

## Winter Annual Grasses

### Winter Annual Grass Control Strategies

- Eliminating weed seed sources in and around the fields is important
- Plant perennial, cool-season grasses such as crested wheatgrass or smooth brome in waste areas and field borders. Vigorous grass or grass-legume stands are highly competitive against winter annual grasses
- Planting weed free seed will help maintain uninfested fields weed free.
- Cleaning combines before harvesting clean fields will limit spread.
- Delaying planting date until after the first flush of weed germination in the fall for winter wheat or in the spring for spring wheat and durum can reduce problems. In addition, tillage is used to initiate weed germination. Plowing is used to bury seed and reduce its germination potential.
- The most effective control option for winter annual grasses is the use of rotations with summer crops to help break the winter annual cycle. The best rotation is to use at least a 4-year rotation, but 3-year rotations will also help to reduce weed pressure. Two-year rotations with late-spring planted crops can be effective, if weeds are adequately controlled in the rotational crops. Crops planted in late spring such as corn, grain sorghum, proso millet, and sunflower are much more effective than crops planted earlier in the spring such as pea, oat, spring barley, and spring wheat. Crops that must be planted early for optimum yield will allow some downy brome enough time to germinate and produce seed.
- The key to control is having fall rains to germinate downy brome seeds and then killing these plants before seeding early spring crops. A glyphosate application followed by tillage 3 to 15 days later is the most effective control method.
- A final important aspect to managing these weeds is to reduce weed seed buildup by maintaining good control of these weeds during the fallow period. Fallow weed control is done using both tillage and herbicide methods. Herbicide treatment for these weeds does occur with Roundup used on very limited acres to control volunteer rye during the spring while the rye is much taller than the wheat and rye seed has not begun developing on the plant.

### **Jointed Goatgrass (*Aegilops cylindrica*)**

Jointed goatgrass is a non-native grass introduced from Turkey in the late 1800s. It is a winter annual, reproducing by seed and grows 15 to 30 inches tall in erect stems which branch at the base to give the plant a tufted appearance. Seeds of jointed goatgrass are attached to their rachis segment and shed in June and July, during and prior to wheat harvest. The seeds are very similar in size and shape to wheat seed and therefore are difficult to screen out. Jointed goatgrass is becoming an increasing problem in the wheat land areas, especially in the winter wheat production areas.

### **“Cheatgrasses”**

Several winter annual grasses invade wheat field in the Northern Great Plains. These grasses often are grouped together and called “Cheat” or “Cheatgrass”. **Downy brome** is one of these grasses and is known by a variety of names including cheatgrass, cheatgrass brome, downy

bromegrass, military grass, wild oats, downy chess and cheat. Two other annual bromes often are confused with downy brome: **Japanese brome** (*Bromus japonicus* Thunb. ex. Murr), which is more common in western areas, such as western Nebraska, and **Hairy chess** (*Bromus commutatus* Schrad), which is more common in eastern areas, such as eastern Nebraska. Both are more prevalent in pastures and waste areas but can be found in winter wheat.

Downy brome is especially troublesome in alfalfa, winter wheat-fallow rotation, continuous winter wheat, rangeland, waste areas, roadsides, shelterbelts, fencerows and railroad rights-of-way. It is a strong invader and creates a serious fire hazard when the mature plant dries. Japanese brome is also a strong invader. It is found in dry or moist waste areas, disturbed sites, roadsides or in fields and is especially prominent in winter wheat.

### **Perennial Grasses**

#### **Quackgrass** [*Agropyron repens* (L.) Beauv.]

Quackgrass, a perennial, is a pest throughout the Northern Great Plains. It has been listed as a noxious weed in the region, and is a noxious weed by seed law throughout the Northern Great Plains. Quackgrass has decreased in importance considerably as a pest in wheat production areas. It thrives on different soil types, in gravel and peat, and also under saline and alkaline conditions. As a perennial sod-forming grass plant, it has an extensive root system and spreads by seed and underground rhizomes. Cultivation and herbicide applications may need to be repeated to eliminate quackgrass problems.

Key prevention and control tactics:

- Plant clean seed—Quackgrass seed often is found in seeds of small grain and bromegrass. Buy only high-quality, tested crop seed from reliable sources that does not contain seeds of quackgrass or other weedy species.
- Avoid spreading or reintroducing quackgrass on contaminated equipment or in irrigation water.
- Avoid infested bedding or feeds—Quackgrass seeds are commonly found as impurities in straw used for bedding or mulching. Do not buy or use any bedding, packing, or mulching materials containing quackgrass seed
- The extensive system of underground roots and rhizomes contains abundant food reserves, enabling quackgrass to resprout after mowing or cultivation. Repeated tillage can control quackgrass by depleting food reserves and preventing manufacture and accumulation of additional reserves.
- Herbicides to control quackgrass are available for most crops. Quackgrass is most effectively controlled by a combination of chemical and cultural methods.

## **Broadleaf Weeds**

**Kochia:** (*Kochia scoparia*). Kochia is an erect bushy annual, two to seven feet in height. It is an exceptionally competitive weed that can cause severe yield losses. This weed is commonly found in most crops across the Northern Great Plains. Kochia has been difficult to control. In many fields 2, 4-D no longer controls kochia adequately. Some kochia populations have become resistant to ALS and dicamba herbicides as well as to triazines used in row crops. Starane provides good control of ALS, triazine and dicamba resistant kochia. Banvel/SGF/Clarity plus MCPA amine, Bromoxynil plus MCPA and Aim + 2, 4-D also provide good control.

### **Others:**

**Redroot pigweed:** (*Amaranthus retroflexus*) is a coarse erect annual, usually two to three feet tall. The lower stems are usually red, with color continuing down to the taproot. Redroot is widely distributed throughout the western states and commonly found in crops across the Northern Great Plains.

**Russian Thistle:** (*Salsola iberica*) is a rounded, bushy, much branched annual, usually one-half to three feet tall. Seeds are spread as mature plants break off at ground level and are scattered by the wind as tumbleweeds.

**Field Bindweed:** (*Convolvulus arvensis*) Field bindweed (creeping jenny) is a perennial weed introduced from Europe that is well adapted to the climate in the northern states. It can be found across the region and has been declared a noxious weed by the state of North Dakota and South Dakota, among other states. Field bindweed can reduce yields by 50 percent, cause lodging, and can make harvest difficult. Intensive cultivation can control newly emerging seedlings, and aid in controlling established bindweed stands by reducing nutrient reserves in the roots. When used in combination with herbicides, cultivation becomes a key part of an effective management program. Control of bindweed requires a long-term management program. Multiple herbicide applications are required to control bindweed.

**Canada Thistle:** (*Cirsium arvense*) Canada thistle is a colony-forming perennial weed with an extensive root system. It has become a major problem as a result of reduced tillage practices, wet weather cycle and lack of effective controls. Canada thistle is an aggressive noxious weed that competes well with small grain for water and nutrients. Periodic tillage on fallow ground is used to control Canada thistle throughout the summer. Tillage keeps the thistle plants in the rosette stage and prevents them from bolting. Following tillage, a herbicide such as glyphosate, Curtail/M, or stinger can be applied to the rosettes in late September or early October. Post-harvest treatments give better thistle control than pre-harvest treatments.

## **Herbicides for Use in Wheat**

1. Herbicides Used Mostly for Annual Broadleaf Control
  - a. Synthetic Auxins- Phenoxys
    - i. MCPA Amine or MCPA Ester
      1. Weak on kochia and wild buckwheat

- ii. 2,4-D Amine or 2,4-D Ester
  1. Best choice for field bindweed
  2. The most widely used herbicide in the region
  3. Less effective on kochia and wild buckwheat
  4. Cost effective
  5. Helps in controlling resistant weed development- critical use
- iii. Dicamba as Banvel or Clarity or Sterling
  1. Tank mix with MCPA or 2,4-D or many other products
  2. Widely used
  3. Adjoining crops can have drift problems (herbicide damage)
- b. Synthetic Auxins- Pyridine carboxylic acids
  - i. Clopyralid as Stinger or in Curtail (clopyralid + 2,4-D) or Curtail M
    1. Primarily used for Canada thistle
    2. Stinger not used in wheat due to economics, Curtail is product that is used
  - ii. Fluroxypyr as Starane
    1. Used as alternative mode of action for ALS herbicide resistant kochia
    2. Is the standard for kochia control
    3. Expensive, so use rate is frequently 40-50% of labeled rate in combination with other herbicides, targeting kochia
  - iii. Picloram as Tordon 22K (RUP)
    1. Used exclusively as a tank-mix with 2,4-D or MCPA in wheat
    2. Used where wild buckwheat a concern
    3. Poor kochia control
    4. Minimum carrier 5 GPA (ground) or 1 GPA (air)
    5. Not for use on durum or winter wheat
    6. Very seldom used, used to treat patches
- c. Photosystem II Disruptors- Nitriles
  - i. Bromoxynil (various products) and bromoxynil tank-mixes
    1. Broad spectrum annual broadleaf control
    2. Excellent wild buckwheat control and good on small kochia
    3. Not for perennial weeds
    4. On winter wheat, may be used alone in the fall for winter annual broadleaves as well as in the spring.
- d. PPO inhibitor- Triazolinones
  - i. Carfentrazone as Aim
    1. Good control of normal and ALS-resistant kochia
    2. Performance more variable than for Starane or for bromoxynil
    3. Not as widely used as Starane or bromoxynil for kochia
- e. ALS/AHAS inhibitors- Sulfonylureas
  - i. General comments
    1. Most SU's are good to excellent on wild mustard, pennycress, Russian thistle, wild sunflower and non-ALS kochia
    2. Most SU' do not provide control of grasses
    3. Many SU's are mixed with phenoxy or other herbicides to improve control

4. ALS resistant weeds are a concern, especially kochia, but also others
  5. Some SU's should not be applied to a crop where certain organophosphate insecticides were applied or injury will occur
  6. Rotational restrictions vary with product, but can be a significant concern
- ii. Thifensulfuron as Harmony GT
    1. Use in western areas is on irrigated ground due to rotation flexibility
  - iii. Tribenuron as Express
    1. Very little soil activity
    2. No rotation restrictions except no planting of any crop except wheat or barley for 60 days
  - iv. Thifensulfuron + tribenuron as Harmony Extra
    1. use out west is on irrigated ground due to rotation flexibility
  - v. Metsulfuron as Ally
    1. Resistance management, especially with ALS kochia is required. Use tank mixes to provide control and no applications more often than 22 months apart.
    2. Use in western areas is on irrigated ground due to rotation flexibility
    3. Can follow it with proso millet in the western part of the region.
  - vi. Thifensulfuron + tribenuron + metsulfuron as Canvas
    1. Rotational restrictions may be a concern
    2. Special consideration for resistance management must be given
  - vii. Triasulfuron as Amber or with dicamba as Rave
    1. Extended soil residual activity compared to other SU's
    2. Downy brome suppression at special rates (5.6 oz/A or 2.5 A/pak). No other grass activity.
    3. Resistance management is a concern.
    4. May be applied as split application on winter wheat.
    5. May be used preplant, preemergence or post emergence on winter and hard red spring wheat
    6. 75% of hard red winter wheat that is sprayed in western NE uses this, important option to have – longer residual than Ally. Always tank-mixed with 2,4-D.
    7. Also used because it can be followed by proso millet
  - viii. Chlorsulfuron + metsulfuron as Finesse
    1. Soil residual to the following season or longer
    2. Labeling includes “cheatgrass” suppression in some geographic areas, but not in South Dakota.
    3. Resistance management significant concern: 36 months between Finesse applications alone and 18 months between Finesse tank-mix applications
  - ix. Prosulfuron as Peak
    1. Wild buckwheat control adequate with tank-mixes. No grass control or ALS kochia control.

2. Herbicides Targeted for Perennial Broadleaf Control
  - a. Synthetic Auxins- Phenoxys
    - i. MCPA Amine or MCPA Ester
      1. Weeds must be small
      2. Equal to 2,4-D on wild mustard, Lambsquarters and Canada thistle
      3. Weak on kochia and wild buckwheat
    - ii. 2,4-D Amine or 2,4-D Ester
      1. Best choice for field bindweed
      2. Amine provides better crop tolerance
      3. Not recommended for fall application on winter wheat
      4. Important/critical use for resistance management
      5. Improves effectiveness of other products on perennials.
    - iii. Dicamba as Banvel or Clarity or Sterling
      1. Tank mix with MCPA or 2,4-D or many other products
      2. Boosts control on weeds like kochia and wild buckwheat
  - b. Synthetic Auxins- Pyridine carboxylic acids
    - i. Clopyralid as Curtail (clopyralid + 2,4-D)
      1. Primarily used for Canada thistle
      2. Also effective for broadleaves like sunflower and cocklebur
      3. Very often tank-mixed with other products, especially 2,4-D, MCPA, bromoxynil, Ally, Express and dicamba.
      4. Apply at 3 leaf to early boot
  
3. Herbicides Used for Resistance Management of ALS Resistant Kochia
  - a. Synthetic Auxins- Phenoxys
    - i. MCPA Amine or MCPA Ester
      1. Weak on kochia and wild buckwheat
    - ii. 2,4-D Amine or 2,4-D Ester
      1. Best choice for field bindweed, but less effective on kochia and wild buckwheat
      2. Amine provides better crop tolerance
    - iii. Dicamba as Banvel or Clarity or Sterling
      1. Tank mix with MCPA or 2,4-D or many other products
      2. Boosts control on weeds like kochia and wild buckwheat
  - b. Synthetic Auxins- Pyridine carboxylic acids
    - i. Fluroxypyr as Starane
      1. Can be used as alternative mode of action for ALS herbicide resistant kochia- is the standard for ALS-resistant kochia
      2. Often tank-mixed with 2,4-D or MCPA products to control additional species
  - c. Photosystem II Disruptors- Nitriles
    - i. Bromoxynil (various products) and bromoxynil tank-mixes
      1. Broad spectrum annual broadleaf control
      2. Excellent wild buckwheat control and good kochia control



3. Not for perennial weeds
- d. PPO inhibitor- Triazolinones
  - i. Carfentrazone as Aim
    1. Often tank-mixed with 2,4-D or MCPA to control additional species of broadleaves
    2. Good control of normal and ALS-resistant kochia. Also fair to good activity on wild buckwheat, pigweed and black nightshade
4. Pipeline Products for Broadleaf Weed Control: None mentioned
5. "To Do" List
  - a. Research Needs- Broadleaf Weeds
    - i. Look at Starane reduced rate applications and the potential for resistance to develop.
    - ii. Evaluate some of the herbicide resistant rotational crops used in rotation with wheat and the function of cost vs. efficiency for these crops
    - iii. Need to get a product that works consistently for Canada thistle control
    - iv. Need to get a product that works consistently for field bindweed control
    - v. Investigate a mite for biocontrol of field bindweed
    - vi. Volunteer flax is a problem weed and there is a need more products to control
  - b. Extension Needs- Broadleaf Weeds: None
  - c. Regulatory Needs- Broadleaf Weeds: None
6. Herbicides Used for Grass Control
  - a. Microtubule Assembly Inhibitors (dinitroanilines)
    - i. Trifluralin as Treflan and many other brands
      1. For foxtail control
      2. Not effective and can cause wheat damage, not widely used
      3. Not for winter wheat or rye, can be used as spring application on spring grains, after planting, shallow incorporated.
      4. No wild oat control, but consistent foxtail control
      5. Can be fall applied, preplant incorporated
  - b. Lipid Synthesis inhibitor (thiocarbamate)
    - i. Triallate as Far-Go
      1. For wild oat control
      2. Spring and durum wheat only
      3. Not often used, less effective than alternatives and can cause wheat injury
  - c. Photosystem II Disruptor (amide)
    - i. Propanil as Stampede (applied only as tank-mix with MCPA Ester)
      1. Contact, non-residual, post-emergence herbicide for foxtail control
      2. Good to very good control of green and yellow foxtail if applied at 1-3 leaf foxtail stage, larger plants less controlled

3. Not used much, better alternatives available
- d. ACCase inhibitors (aryloxyphenoxy propionates or “fops”)
  - i. Fenoxaprop as Puma
    1. Controls emerged green and yellow foxtail, volunteer and wild proso millet, corn, barnyardgrass and wild oats
    2. Wild oat control very good to excellent in SDSU tests, resistance seen already in ND and MN
    3. Widely used, trend is for increase in use in North Dakota
    4. Often tank mixed for broadleaf control
  - ii. Clodinafop as Discover
    1. For wild oats and barnyardgrass
    2. Strength is wild oats, tank mixed with broadleaf products – good tank mix partner
- e. ACCase inhibitors (cyclohexanediones or “dime”)
  - i. Tralkoxydim as Achieve
    1. Winter wheat and barley only
    2. Post-emerge control of wild oats, green and yellow foxtail and volunteer oat
    3. Yellow foxtail appears less sensitive than green foxtail
    4. No longer labeled in SD and parts of MN, and limited label in ND due to crop injury
    5. Isolated resistance has been seen
- f. ALS inhibitors (sulfonylureas or “SU”)
  - i. Sulfosulfuron as Maverick
    1. Will control annual grasses and some broadleaved weeds. Primary targets are downy brome and Japanese chess in winter wheat.
    2. Will control wild oat, but not well controlled if fall application used
    3. Works reasonably well on cheatgrass, applied late fall or early spring, does need moisture, can be followed by proso millet
- g. ALS inhibitors (imidazolinones or “IMIs”)
  - i. Imazamethabenz as Assert
    1. Provides wild mustard and wild oat control. Does not control foxtail – which limits use
    2. Can be used on winter wheat, spring wheat, durum or barley
    3. Is a tool for management of wild oat resistant to other herbicide classes
- h. ALS inhibitors (triazolinones)
  - i. Flucarbazone as Everest
    1. Green foxtail (low rate) and wild oat (high rate) control. Yellow foxtail is suppressed.
    2. Not used much, wheat injury concern
    3. Different mode of action for wild oat control, tool for resistance management
- i. Unknown Mode of Action (pyrazoliums)
  - i. Difenzoquat as Avenge
    1. Post-emerge wild oat control

2. Varietal limitations. Varietal limitations for hard red winter wheat, hard red spring wheat, durum and barley are listed on the label
  3. Not widely used
7. Pipeline Products for Grass Control:
- a. Pending registration of mesosulfuron will provide a different mode of action for resistance management
8. “To Do” List
- a. Research- Grass Control
    - i. resistance issue with wild oats
    - ii. resistance management, rotation of mode of action
    - iii. entire list of herbicides – look at antagonist issue
    - iv. yellow foxtail and barnyardgrass control as a weed issue
    - v. Winter annual grasses are a significant concern. The biggest problem is jointed goatgrass. Once it is established have to rotate away from wheat for 3-4 years. Wheat is the primary crop so a rotation away from wheat is a big problem. Jointed goatgrass is a quality problem also.
    - vi. Where jointed goatgrass is not a problem then downy brome grass is a big problem. Control is difficult.
    - vii. Feral rye is also a problem – a quality problem for the winter wheat crop at marketing time.
    - viii. Rotational flexibility with herbicides, carryover is a problem
    - ix. Atrazine is an important rotational herbicide at fall applications. At low level usage, not close to water. It is inexpensive, easily applied and effective
    - x. Need control options for yellow nutsedge
  - b. Education/Extension- Grass Control
    - i. Education on the antagonist issue overall for herbicides
  - c. Regulatory- Grass Control
    - i. Pending registration of mesosulfuron
    - ii. Carrier volumes are critical issues and can become a problem because the minimums are excessive.
9. Herbicides For Pre-Harvest Application (Harvest Aids)
- a. Synthetic Auxins- Phenoxys
    - i. 2,4-D Amine or 2,4-D Ester
      1. Do not use for straw of feed
    - ii. Dicamba as Banvel or Clarity or Sterling
      1. Labeled on spring and winter wheat
      2. Do not graze or feed straw from treated fields
      3. Test germination if crop is used for seed purposes
  - b. ALS/AHAS inhibitors- Sulfonylureas
    - i. Metsulfuron as Ally

1. Winter and spring wheat
2. Do not feed straw or graze stubble
- c. EPSP synthase inhibitors (glycines)
  - i. Glyphosate (several brands and formulations)
    1. Not suggested for seed fields

## 10. Herbicides Used for Burndown and Post-Harvest

- a. PSI disruptors (bipyridiliums)
  - i. Paraquat as Gramoxone
    1. Non-selective, contact herbicide without residual
    2. Highly toxic- use care in application
- b. EPSP synthase inhibitors (glycines)
  - i. Glyphosate (several brands and formulations)
    1. Non-selective, translocated herbicide without residual
    2. Use caution to avoid drift
- c. PPO inhibitor (triazolinones)
  - i. Carfentrazone as AIM EW
    1. Annual weed up to 3 inches tall and rosettes less than 3 inches
- d. Synthetic Auxins (quinolines)
  - i. Quinclorac as Paramount
    1. Control of annual grass (foxtail and barnyardgrass) and broadleaved weeds in fallow and preplant wheat
    2. Especially useful for field bindweed and volunteer flax
    3. Avoid drift to non-target plants

## **XI. Stored Grain Pests and IPM Strategies**

There are many pests that attack stored grain products, including wheat. Insects, rodents, birds and other organisms such as storage molds are possible pests in stored grain. With proper harvesting, handling and storage techniques in an integrated pest management program, most insect storage pest problems can be avoided. During the PMSP Meeting, a need for effective products was raised as there are currently only limited effective products available. Much of the information in the following section has been adapted from information kindly shared by Dr. Jim Criswell and Charles Luper of the Oklahoma Program of the Southern Region Pest Management Center. A more complete discussion of stored grain pest management in winter wheat in Oklahoma will be included in the strategic plan for stored wheat in Oklahoma which is forthcoming from that program. Additional sources used are listed in the bibliography for this section.

### Grain Harvest and Pre-Storage Grain Preparation

The importance of proper harvesting and grain preparation prior to storage cannot be overlooked when looking at pest management. High grain moisture and the presence of high-

moisture, foreign material such as weed seeds lead to greater levels of humidity in the grain as a whole, and without adequate cooling, this increased humidity can lead to increased mold growth and increased insect activity. A 13% moisture level or less is generally recommended. Foreign material can be greatly reduced through proper combine setting to reduce cracked seed (fines) or by on-farm cleaning, if necessary. On-farm cleaning has not been a common practice but has increased in recent years due to *Fusarium* outbreaks in the northern areas of the region.

### Sanitation of the Storage Facility

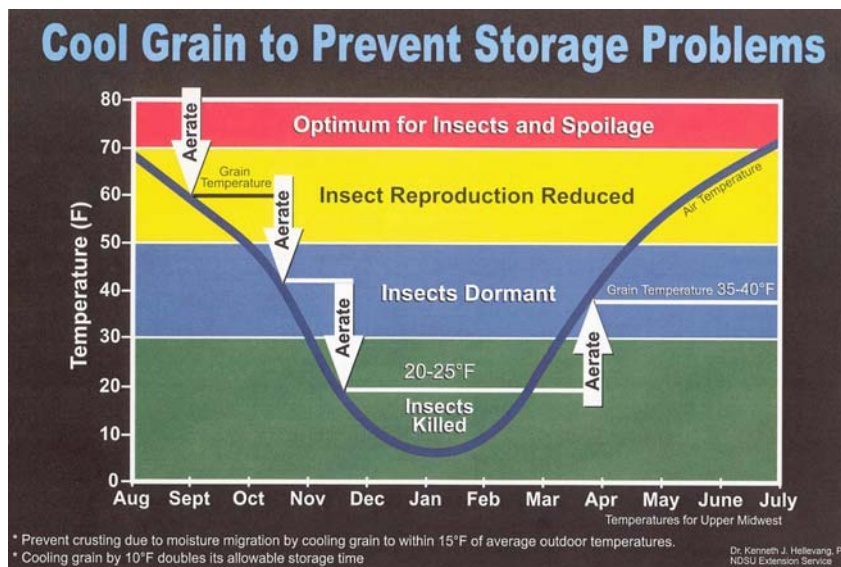
Sanitation is the primary key to prevention of pest infestation in all grain storage facilities. Maintaining a clean grain storage facility, both inside (including areas below slotted aeration floors) and outside on the ground will reduce potential pest problems significantly. Sound management practices include: 1) Clean outside around the bin, beneath perforated floors and inside ducts in addition to cleaning the bin. If you can tell what has previously been in the bin, it is not considered clean, 2) Fumigate areas that are not easily accessible, if needed (usually professionally done), 3) Store new crop grain only in cleaned, empty bins and 3) Use a residual bin spray to treat the inside surfaces of the empty bins at least two weeks prior to filling, if infestations were a problem.

#### (i) Aeration and Cooling

In the Northern Great Plains, cooling the grain mass prior to winter storage is extremely important in preventing insect infestations in stored grain. Aeration of the grain mass in storage serves two primary purposes, both of which are related to grain temperature. The first is to cool the grain to match the cooler external environmental conditions (such as in late fall and winter months). The second is for drying the grain to remove excess moisture or to prevent moisture buildup in uneven grain masses.

Aeration for temperature control in the grain is best accomplished by drawing cold air through the grain mass. Some systems move air down through the grain and out through exhaust fans at the bottom of the bin. However, many on-farm storage facilities are now equipped with fans that operate by blowing air under positive pressure through the grain from the bottom up.

Temperature monitoring is critical in stored grain pest management, as stored grain insect pests show very little activity when grain temperatures are cold. Once the temperature drops below 70 degrees, insect reproduction slows down and stops altogether at 60 degrees. At 50 degrees, insects become dormant. Ideal winter storage temperatures are around 25 degrees. This temperature will kill many insects in grain, and these temperatures are attainable in the Northern Plains area. Higher temperatures allow for increased insect growth and



breeding. Monitoring can be done with handheld temperature devices or with electronic temperature probes, depending on the size of the storage facility and the investment in monitoring equipment desired. The figure at right shows the ideal temperature curve and timeline for stored grains in the Northern Great Plains area (Hellevang, 2003).

### Monitoring

Monitoring grain conditions at regular intervals throughout the storage period is extremely important. Careful and repeated scouting for stored grain problems, including grain quality (heating), temperature, insects and environmental problems (such as leaks), evidence of rodent damage and droppings or any odors that may be present is critical. Insect pests and grain quality at various locations within the bin should be monitored regularly throughout the storage period. Insect pests generally infest the top and bottom layers of grain in a facility.

### Insect Pests

Insect pests in stored grain can be grouped based on their type of damage. Insect pests may be primary pests (internal feeders) or secondary pests (external feeders, many times called “bran bugs”) and surface feeders.

### **Internal Feeders in the Northern Plains**

**Lesser Grain Borer** (*Rhyzopertha dominica*) can be a destructive insect pest of stored wheat in the region, but is less common than some others. This insect is a strong flier that can tolerate high temperatures and dry grain (moisture content less than 12%). The insect feeds and destroys the whole grain and can reproduce rapidly. Adults and larvae have powerful jaws that are used to create large, irregular-shaped holes in the grain. Heavy infestation with lesser grain borers can be identified by a sweetish, musty odor in the storage.

*Resistance* - Lesser Grain Borer has shown high resistance to malathion and moderate resistance to Reldan; thus the insect is not listed on the Reldan label. A light to moderate resistance has been found to phosphine gas in Oklahoma.

**Granary Weevil** (*Sitophilus granaries*). The granary weevil is also of lesser importance in the region than some others but is still present. The insects develop inside whole grain kernels as small, white, wrinkled, grub-like larvae. There is generally no external evidence that the larvae have been eating and growing inside the seed until after about one month when the adult weevil chews through the seed coat and emerges. The adult weevils are 1/8th inch long and have slender, hard-shelled bodies that appear pitted or scarred with tiny holes. They are brown to reddish brown in color. The granary weevil is uniformly colored with no spots.

### **External Feeders**

**Red Flour Beetle** (*Tribolium castaneum*) and the **Confused Flour Beetle** (*Tribolium confusum*) are very common and important external feeding insects in the region. *Tribolium confusum* cannot fly, but *Tribolium castaneum* may fly. These beetles are common in milled products, but may also be present in stored grain. The insects reproduce faster when some fine material is present in the stored grain, especially if grain moisture is more than 12%. Beetles cannot grow and reproduce on undamaged grain. A pungent, bad odor in the grain is a sign of high

infestations with red flour beetles.

**Sawtoothed Grain Beetle** (*Oryzaephilus surinamensis*) and **Merchant Grain Beetle** (*Oryzaephilus mercator*) are common insects in stored grain, cereals, and milled products. The larvae develop in flour, cereal products, and many other dried products. Eggs are deposited on cracks in the kernels and adults and larvae feed on damaged kernels, fines, and occasionally the germ of the intact grain.

### **Other insects**

**Indianmeal Moth** (*Plodia interpunctella*) is a serious pest that attacks stored grain and cereal products. It is capable of infesting any cereal grains or milled products. The Indianmeal moth is a surface feeder whose larvae infest and cause damage to the grain and spin silk over the grain surface. This silk is a nuisance, blocks off aeration, and can be a cause of grain heating from increased moisture. Adult moths are short lived and do not feed.

**Foreign Grain Beetle** (*Ahasverus advena*) does not feed on the grain itself, but on fungi that grow on high moisture grain. Their presence is an indication of moldy grain, so, conversely, well-managed grain is typically not infested with these beetles. Populations are kept under control if proper sanitation techniques are used and the grain moisture level is maintained at less than 13%.

**Booklice.** (Psocids) These tiny insects are often found in very large numbers in stored wheat. They are not known to damage wheat nor to feed on the kernels or broken kernels. Presence of booklice may rarely require control but should not result in the classification “infested” grain.

**Mites.** Mites are occasionally found in stored wheat. They are not known to damage wheat, but will feed on wheat germ, broken kernels or mold. Some mites are predators of insects and other mites.

### **Other Pests**

#### **Rodents and Birds**

Two rodents are of a common concern to grain storage facilities, namely house mice (*Mus musculus*) and Norway rats (*Rattus norvegicus*). Rodent droppings are a significant concern to the marketability of stored grain. In addition, building and equipment damage and the nuisance of the burrows, nests, etc. make control and prevention of these animals a priority.

Numerous bird species are common pests of stored grain facilities. Birds consume and contaminate grain with their droppings and feathers.

#### **Fungi (Mold)**

Simply stated, fungi in stored grain are controlled by controlling storage conditions, not fungicides. Any condition that increases moisture in the grain storage can allow for the growth of mold. Field molds, such as *Fusarium* (*Giberella*) and *Aspergillus*, both which can produce toxins, and *Diplodia* can affect stored grain. Storage molds, such as *Aspergillus* and *Penicillium*

are also concerns. Control is accomplished by reducing and maintaining even grain moisture and by controlling grain temperature and quality going into storage.

## **Pesticide Treatments for Stored Grain**

### **Insects and Related Arthropods**

**Empty-Bin Treatments** include residual insecticides applied in and around the fan, aeration ducts, auger, door openings, and hatch covers, or fumigants, before bins are filled at harvest. Insecticides registered in the region include:

**Grain protectants** are insecticides sprayed directly onto grain going into the storage or already in storage. Grain protectants do not kill insects inside the kernels.

#### Limitations to protectants

There are several limitations of the effectiveness of the protectant insecticides. Resistance to malathion is quite common and as a result, malathion will not control Indian meal moths. Neither Reldan nor malathion will control lesser grain borers. Storcide is not currently registered for international trade, as there is no set international residue limit (Codex MRL) for one of the components of the product. It is very important to note that in situations where grain drying is necessary, an insecticide protectant should be applied after the grain has gone through the drier. Commercial grain driers generate enough heat to rapidly degrade insecticides applied to grain prior to the drying process.

**Table 5. Insecticides Labeled for Use as Empty Bin Treatments in South Dakota, 2004**

<b>Active Ingredient</b>	<b>Example Brands</b>	<b>Comments / Usage</b>
Chlorpyrifos-methyl	Reldan 4E	Can only be applied from outside of bin and sprayed downward into the bin. Reldan does not control Lesser Grain Borer.
Chlorpyrifos-methyl + cyfluthrin	Storcide	Can only be applied from outside of bin and sprayed downward into bin. Do not use on export-bound grain.
Cyfluthrin	Tempo Sc Ultra Premise Spray	Most effective residual as compared with malathion and chlorpyrifos-methyl. Cyfluthrin will Control Lesser Grain Borer.
Malathion	Malathion	No longer recommended for empty grain bins because of high insect resistance and rapid degradation in warm, relatively moist grain.
Diatomaceous earth	Insecto, Protect-it	Excellent empty bin treatment. Special grade required for grain use. Must use DE labeled for grain.
Chloropicrin	Chlor-o-pic	Empty bin fumigant, under false floor, aeration tubes, and tunnels.
Methyl bromide	Brom-o-gas, others	Empty bin fumigant; seldom used.
Phosphine	Phostoxin, others	Empty bin fumigant.
<i>Bacillus thuringiensis</i>	Dipel	For moth larvae only. No effect on other pests.



**Table 6. Insecticides Labeled for Use as Grain Protectants in South Dakota, 2004**

Active Ingredient	Form	Example Brands	Comments
Chlorpyrifos-methyl	Liquid	Reldan 4E	Reldan does not control lesser grain borer. Can only be applied from outside of the bin and sprayed downward into the bin.
Chlorpyrifos-methyl + cyfluthrin	Liquid	Storcide	Can only be applied from outside of the bin and sprayed downward into the bin. Do not use on export-bound grain.
Malathion	Liquid	Malathion 5EC	Most stored grain insects are resistant.
DDVP	Liquid	Vapona	Also as strips for use in headspace above grain.
Methoprene	Liquid	Gentrol, Zoecon Diacon II	Kills developing insects only, slow kill of larvae, no kill of adults though causes sterility. High cost and must use other products before sale. Newly marketed.
Pyrethrins	Liquid	Pyrenone	Expensive and short residual.
Malathion	Dust	Dust	Top-dress treatment. Most insects are resistant. Millers resist purchasing grain with strong malathion odor.
Diatomaceous earth	Dust	Protect-It, Cringe, Insecto	Can lower the test weight of grain and is expensive if applied to entire grain mass, so is best applied to empty bins and to the top and bottom layers of the grain mass.

### Fumigants

When other control methods are not possible and insect populations warrant control measures, fumigation of stored grain is commonly practiced. Safety of the applicator doing the pest control in this manner is critically important, and as a result, many times the application is done professionally.

Fumigants registered for use in the region are phosphine, either released from aluminum or magnesium phosphide or directly as a gas, methyl bromide, and chloropicrin (used for empty bin treatment only). Aluminum or magnesium phosphide, usually sold as tablets or packs of tablets includes the brand names Phostoxin, Weevilcide, Fumitoxin, and possibly others. Commercial applicators may also have access to gaseous fumigants, such as methyl bromide or a mixture of carbon dioxide and phosphine gas in a compressed cylinder as ECO<sub>2</sub>Fume. Methyl bromide has many limitations and is not common in the area, but still present.

The phosphide pellets or tablets release hydrogen phosphide (phosphine) gas as they are exposed to moisture in the air. Phosphine is heavier than air and settles through the grain mass. Air circulation within the facility can help distribute the gas effectively. Application is by spreading tablets on the surface of grain, probing tablets into the surface layers, or automatically metering tablets into flowing grain as it enters storage. For an effective fumigation, the facility must be well sealed to prevent gas leakage to maintain a high enough dosage for sufficient time to kill all life stages of the infesting insects.

Methyl bromide is currently being phased out. As a result, phosphine will be the only remaining fumigant for stored grain. Its' continued availability is therefore an important issue.

### Pipeline Materials

Three new products are known to be in the "pipeline" to be registered and available for use within the next year or two. Profume (Sulfuryl fluoride) - a tolerance recently granted and registration for cereal grains has been approved. Storcide II (Chlorpyrifos-methyl + deltamethrin) - Effective and has a codex MRL for both a.i. but does not have a US tolerance for

deltamethrin at this time. Spinosad not yet labeled for stored grain but has a tolerance for wheat grain and can be used on wheat in the field.

## References

- Criswell, J., C. Luper, et al. Pest Management Strategic Plan- Stored Hard Red Winter Wheat- Oklahoma. Unpublished to date. Used with permission.
- Hellevang, K. 2003. Grain Cooling Chart. Online at: <http://www.ag.ndsu.nodak.edu/abeng/CoolGrainChart.gif>. North Dakota State University Extension.
- Lewis, D. 1996. Iowa Insect Information Notes. Various pages. Online at: <http://www.ipm.iastate.edu/ipm/iiin>.
- Steffey, K.L., B.E. Paulsrud, P.D. Bloome, P.L Nixon and D.G White. 1997. Grain Facility Pest Control. Illinois Pesticide Applicator Training Manual 39-8. University of Illinois-Urbana-Champaign.

## XII. Efficacy Tables

**Table 7. Efficacy of Insecticides Currently Registered on Stored Grain<sup>1</sup>**

	Fumigants			Organophosphates			Other Pesticides						
	Phosphine	Chloropicrin	Methyl Bromide	Chlorpyrifos-methyl	Malathion	DDVP	Cyfluthrin		Pyrethrins		Diatomaceous Earth	<i>Bacillus thuringiensis</i>	Methoprene
<b>Internal Grain Feeders</b>													
Lesser Grain Borer	G	E	E	P	R	--	G		P		E	--	E
Rice Weevil	E	E	E	E	R	--	P		P		E	--	E
<b>External Grain Feeders</b>	E	E	E	E	R	--	E		P		E	--	E
<b>Mold Feeders</b>	E	E	E	E	R	--	E		P		E	--	E
<b>Indianmeal Moth</b>	E	E	E	E	R	E	E		G		E	E	E

<sup>1</sup> From Oklahoma Stored Grain Strategic Plan.

<sup>2</sup> Efficacy abbreviations E = Excellent, G = Good, P = Poor, R = Resistant, -- = not used against that pest

**TABLE 8. WEED AND CROP RESPONSE TO HERBICIDES**

**WEED RESPONSE.** Weed control percentages are intended as a guide for comparing alternatives. Percentages are estimated based on favorable conditions. E = Excellent; G = Good; F = Fair; M = Marginal, P = Poor.

**CROP RESPONSE.** Crop response is based on visual symptoms. Early-season symptoms do not necessarily cause yield losses. N = None; VS = Very slight; S = Slight; M = Moderate; H = High; + = usually high part of range.

From: Wrage, L.J. and D.L. Deneke. 2004. Weed Control in Small Grains and Millet, FS 525-A. South Dakota Cooperative Extension Service. South Dakota State University. Brookings, SD

Herbicide	WEED RESPONSE											CROP RESPONSE			
	Green Foxtail	Yellow Foxtail	Wild Oats	Gen. Broadleaves	Wild Buckwheat	Kochia (non-ALS)	Kochia (ALS)	Sunflower, Cocklebur	Mustard	Canada Thistle*	Field Bindweed*	Oats	Barley	Wheat	Proso Millet
2,4-D ester	P	P	P	G	F+	F	F	G+	E	G	G	H	S+	S+	--
2,4-D amine	P	P	P	G	F	M	M	G	E	G	G	S	S	S	M
MCPA ester	P	P	P	F	M	P	P	F+	E	G	M	VS	VS	VS	--
MCPA amine	P	P	P	F	M	P	P	F	E	G	M	VS	VS	VS	--
Dicamba + 2,4-D or MCPA	P	P	P	G+	E	G+	G+	G	G	G	F+	--	H	M+	M+
Bromoxynil	P	P	P	F+	E	G	G	G+	F	P	P	M	VS	VS	--
Bromoxynil/MCPA	P	P	P	G+	E	G+	G+	E	G+	F	P	S	VS	VS	--
Avenge	P	P	G+	P	P	P	P	P	P	P	P	--	S+	M	--
Assert	P	P	G+	M	F	M	M	P	E	P	P	--	VS	VS	--
Far-go	P	P	G	P	P	P	P	P	P	P	P	-	VS	S	-
Achieve	G	F	G+	P	P	P	P	P	P	P	P	--	S	-	--
Treflan	G	F+	M	P	P	P	P	P	P	P	P	--	VS	VS	--
Buckle	F+	M	G	P	P	P	P	P	P	P	P	--	VS	--	-
Amber	P	P	F+	G+	F+	E	P	E	E	M	P	--	VS	VS	--
Ally	P	P	P	G+	G+	G+	P	G	E	M	P	--	S	VS	--
Harmony GT	P	P	P	G	E	E	P	E	E	F	P	M	-	VS	-
Harmony Extra	P	P	P	G+	G	G+	P	G+	E	F	P	M	VS	VS	-
Express	P	P	P	G	F	G+	P	G+	E	F+	P	--	S	VS	--
Finesse	P	P	P	G+	G+	E	P	E	E	F	P	--	--	VS	--
Peak	P	P	P	G+	G	G+	P	G+	E	F	P	S	VS	VS	S
Ally Extra	P	P	P	E	E	E	P	E	E	F	P	-	VS	VS	-
Maverick	P	P	G	F	M	M	P	F	E	P	P	--	--	VS	--
Tordon + MCPA	P	P	P	F+	E	M	M	F+	G	G	F	S	S	S	--
Curtail	P	P	P	G	G	G	G	G	G+	E	M	S	S	-	-
Stinger	P	P	P	M	F	P	P	G	P	E	P	VS	VS	VS	--
Express	P	P	P	G	F	G+	P	G+	E	F+	P	--	S	VS	--
Starane	P	P	P	M	F	E	E	G	F	M	M	VS	VS	VS	-
Aim	P	P	P	G	F+	G+	G+	M	M	P	G	M	--	M	-
Puma	E	F	E	P	P	P	P	P	P	P	P	--	S	VS	--
Everest	E	M	G+	P	P	P	P	P	P	P	P	--	--	VS	--
Discover	G+	F	E	P	P	P	P	P	P	P	P	--	--	VS	--
Stampede	G+	M	P	F+	G	F+	F+	F	E	P	P	S+	S+	S+	-
Beyond (Clearfield Wheat)	G	M	F+	G+	F	G+	P	E	E	M	P	--	--	VS	--

\*Topgrowth suppression

- = not labeled

### **XIII. PMSP Meeting Attendees**

Jack Campbell  
University of Nebraska- Lincoln  
WCREC, 461 W University Dr  
North Platte NE 69101-7756  
308-532-3611  
[jcampbell1@unl.edu](mailto:jcampbell1@unl.edu)

Marty Draper  
SDSU Cooperative Extension Service  
PSB 113, Box 2108, SDSU  
Brookings SD 57007-1090  
605-688-5157  
[draper.marty@ces.sdstate.edu](mailto:draper.marty@ces.sdstate.edu)

Phil Glogoza  
North Dakota State University  
Hultz Hall 202, PO Box 5346  
Fargo ND 58105  
701-231-7581  
[pglogoza@ndsuxt.nodak.edu](mailto:pglogoza@ndsuxt.nodak.edu)

Gary Hein  
University of Nebraska- Lincoln  
Panhandle Research & Extension Center  
4502 Ave I  
Scottsbluff NE 69361  
308-632-1369  
[ghein1@unl.edu](mailto:ghein1@unl.edu)

Lynnae Jess  
NCR Pest Management Center  
B18 Food Safety and Toxicology  
Michigan State University  
East Lansing MI 48824  
517-432-1702  
[jess@msu.edu](mailto:jess@msu.edu)

Shripat Kamble  
University of Nebraska- Lincoln  
201A PI  
Lincoln NE 68583-0816  
402-472-6857  
[skamble1@unl.edu](mailto:skamble1@unl.edu)

Darrell Deneke  
SDSU Cooperative Extension Service  
239 Ag Hall, Box 2207A, SDSU  
Brookings SD 57007-1096  
605-688-4595  
[deneke.darrell@ces.sdstate.edu](mailto:deneke.darrell@ces.sdstate.edu)

Randy Englund  
SD Wheat Commission  
116 N Euclid, PO Box 549  
Pierre SD 57501  
605-773-4645  
[renglund@midco.net](mailto:renglund@midco.net)

Gordon Haug  
SD Dept of Agriculture, Office of  
Agronomy Services  
523 East Capitol Ave  
Pierre SD 57501-3182  
605-773-3724  
[gordon.haug@state.sd.us](mailto:gordon.haug@state.sd.us)

Char Hollingsworth  
Northwest Research and Outreach Center  
114 Agricultural Research Center (ARC)  
Crookston MN 56716  
218-281-8627  
[holl030@tc.umn.edu](mailto:holl030@tc.umn.edu)

Virgil Jons  
Agassiz Crop Consulting  
3037 16th Ave S  
Moorhead MN 56560-3912  
218-236-6774  
[soilismylife@att.net](mailto:soilismylife@att.net)

Brian Lacey  
33157 - 320th Ave.  
Wendell MN 56590-9751  
218-458-2595  
[bdlacey@runestone.net](mailto:bdlacey@runestone.net)

Will Lanier  
Montana State University  
422 Leon Johnson Hall  
Bozeman MT 59717  
406-994-5690  
[wlanier@montana.edu](mailto:wlanier@montana.edu)

Satoru Miyazaki  
IR-4 Regional Field Coordinator  
182 Food Safety and Toxicology  
Nat'l. Food Safety and Toxicology Center  
Michigan State University  
East Lansing, MI 48824-1302  
517-432-3100 ext 150  
[ncir4@msu.edu](mailto:ncir4@msu.edu)

Jim Peterson  
North Dakota Wheat Commission  
4023 State St  
Bismark ND 58503  
701-328-5111  
[jpeterso@ndwheat.com](mailto:jpeterso@ndwheat.com)

Kari Salvorson  
Angel Crop Consulting  
30231 120th St  
Mound City SD 57646  
605-955-3522  
[rks2@valleytel.net](mailto:rks2@valleytel.net)

John Larson  
USEPA Region 8  
999 18th St, Suite 300  
Denver CO 80202-2466  
303-312-6030  
[larson.john@epa.gov](mailto:larson.john@epa.gov)

Larry Olsen  
NCR Pest Management Center  
B18 Food Safety and Toxicology  
Michigan State University  
East Lansing MI 48824  
517-355-3459  
[olsenl@msu.edu](mailto:olsenl@msu.edu)

Milton Rogers  
1134 5th, PO Box 806  
Chappell NE 69129  
308-874-2962  
[mrogers@megavision.com](mailto:mrogers@megavision.com)

Leon Wrage  
SDSU Cooperative Extension Service  
229 Ag Hall, Box 2207A, SDSU  
Brookings SD 57007-1096  
605-688-4591  
[wrage.leon@ces.sdstate.edu](mailto:wrage.leon@ces.sdstate.edu)